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Industrial research and development: a management challenge.

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INDUSTRIAL RESEARCH AND DEVELOPMENT: A MANAGEMENT CHALLENGE

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INDUSTRIAL RESEARCH AND DEVELOPMENT

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A MANAGEMENT CHALLENGE

by

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PREFACE

"Today, no one but a fool would share the opinion of Henry Ellsworth, the Patent Commissioner, who in 1845 recommended the closing of the U. S. Patent Office because he thought everything useful to man had already been invented."[1]

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[1] Elliot F. Higgins, "New Product Development--Selection--Coordination--Financing," National Industrial Conference Board Report, No. 40 (New York: National Industrial Conference Board, Inc., 1950), p. 3.

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INTRODUCTION

Today research and development is big business. The United States is spending more money for research and development in one year than was spent between the signing of the Declaration of Independence and the end of World War II. Since the late 1940's the results of industrial research have been spectacular. The advances in space technology, weaponry, and other technological advances have emphasized the point that management can only sense what may affect its operations about a year or two ahead. This point is further reinforced by the development of whole new industries, such as the multi-billion dollar electronic computer industry. Here the significant point to management is not the fact of innovation, or even its size, but the fact that the original developments of computers were made by newcomers, not well established large producers of business machines and associated equipment. The well established, large companies found themselves forced into the field by competition. Therefore, today few industrial executives will dispute that research is needed for competitive survival alone, to say nothing of growth and diversification.

In a recent report the National Science Foundation had this to say about research and development:

> Industry's quest for continued progress in science and technology to meet the demands of the Nation's aerospace, defense, and welfare programs, as well as the competitive search for new products and processes, has made research and development one of the fastest growing activities in the industrial sector of the economy. The spectacular accomplishments in science and technology in such diversified fields as electronics, nuclear energy, space exploration, and medicine in recent years highlight the crucial importance of research and development in the modern world.[1]

With the amount of money being spent each year for R and D, managers are thinking more and more about the results obtained from research expenditures. Today researchers and scientists have been taking the credit for changing the world, but what is the real worth of research in a corporation?

The question that must be asked is whether shareholders are getting projects or profits from research. Research can be an insidious leech on profits and costly to the shareholder if not properly managed.[2]

What are the objectives of research and development in the company? R and D can be targeted toward the reduction of costs, improvement in product quality, the reduction of maintenance costs, the development of new products, better use of present products, development of substitutes for

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[1]National Science Foundation, "Research and Development in American Industry, 1961," Reviews of Data on Research and Development, NSF 62-32, No. 36, September, 1962 (Washington: U. S. Government Printing Office, 1962), p. 3.

[2]Maurice Nelles, "Has Research Been Oversold?" Industrial Research, IV (March, 1962), 19.

existing products and processes, and a multitude of other uses.

Research is expected to pay off. How do we evaluate R and D and what yardsticks do we use?

Control is ever present in management circles. A problem exists in R and D to strike a happy balance between control, and yet allow a freedom of creative effort on the part of the scientist. How are some of these principles of control applied and what are the tools of control at the disposal of management?

How much money should be spent on R and D? A company cannot spend so much that nothing is left for tooling and promotion of the product. A company that spends money on research without having set aside venture capital for exploitation of research results is buying a useless piece of equipment.

> XYZ Company, for example, actually was successful in developing a fuel cell for a specialized application. But to fit the detailed specifications of the application, almost $3 billion was required for the design of an engineering prototype and product equipment. Because the budget was expended in the research, no funds were available for tooling and the project was scrapped.[1]

Dollar returns on R and D investment may be slow. Product or process improvement takes on the average of one to two years to complete. New product or process development may take from five to ten years. Fundamental or basic

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[1]Harold W. Rice, "Realistic Research Administration," Industrial Research, III (June-July, 1961), 63.

research is a real gamble, for here the scientist is seeking new knowledge. Yet basic research is what produces new products and processes which may pay off by profits when uses are commercialized.

The foregoing discussion indicates to some extent the wide scope of the problems involved in research, and the need to plan and manage same. The <u>need</u> is hardly in doubt, but the <u>how</u> is the question that must be answered.

Three management groups are directly involved:

1. Top management knows that their organizations must engage in research and are aware that this function of their business is risky, competitive, and costly. They are aware that better techniques must be found to evaluate, organize, and control research activities within their jurisdiction.

2. Research directors who are confronted with project and program selections are constantly aware of return on investment and the technical feasibility of their projects. They must also cope with budgets, capital investment requests, recruitment of technical personnel, etc.

3. Controllers, while unfamiliar with the details of research and development, are, nevertheless, concerned with research budgeting and the control of costs.[1]

Willard C. Asbury, Vice-President of Esso Research and Engineering Company, has this to say about industrial research.

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[1]Carl Heyel, "Industrial Research Today," <u>Handbook of Industrial Research Management</u>, ed. Carl Heyel (New York: Reinhold Publishing Corp., 1959), pp. 13-14.

> Industrial research today is no longer to be looked upon as a staff or service activity; rather, it is an operation engaged in creating a product. This product is technology, a tool that should be provided at an attractive cost to, and used by, other areas of the company's operations.
>
> Successful management of industrial research, therefore, requires taking the attitude that this is a business, to be managed as a business. Successful management calls for a careful planning to meet the needs: proper selection, establishment, and direction of the research projects, and the careful control over the costs so that the technology is created at an outlay that will make it economically useful.[1]

Gilbert Kelton, Program Manager of Emerson Research Laboratories, in discussing the need for an R and D organization makes the following statements:

> First, clear-cut objectives should be defined. These might include over-all company objectives, customer-company objectives, and program objectives. Second, a "modus operandi" should be established. It may be somewhat flexible, but always in keeping with the desired objectives. Third, the framework should be such that it will tend to aid rather than hinder the overall operation. Finally, evaluation and re-evaluation should be an integral facet of organization in order to determine the effectiveness of an operation, . . .[2]

It is the purpose of this thesis to study some of the planning, organizing, controlling, coordinating, and evaluating management techniques as applied to the environment of today's industrial research and development administration.

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[1]W. C. Asbury, "Establishing Research Projects," Handbook of Industrial Research Management, ed. Carl Heyel, p. 183.

[2]Gilbert Kelton, "Program Management: Panacea or Pandemonium," Research Management, V (January, 1962), 60.

DEFINITIONS

The lack of generally accepted terminology is one of the major problems in discussing research and development management and administration. Therefore, before continuing, and in order to eliminate semantic problems, it might be well to define the general terms associated with industrial research and development (hereafter also referred to as R and D).

> Research and Development are defined as basic and applied research in the sciences (including medicine) and in engineering, and design and development of prototypes and processes. The definition does not include quality control, routine product testing, market research, sales promotion, sales service, research in the social sciences or psychology, or other non-technological activities or technical services.
>
> Research is theoretical analysis, exploration, and experimentation directed to the increase of knowledge and thereby the power to control phenomena.
>
> Development is the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes.
>
> Pure Research is a search for facts and knowledge without any reference to their application. The motivation for this research usually is scientific curiosity.
>
> Fundamental Research is a search for new knowledge in a general field without any reference to specific applications. The motivation for this research usually is the realization that any discovery in

> the general field being explored will probably permit its application by the organization doing the work.
>
> Basic Research represents original investigation for the advancement of scientific knowledge, which does not have specific commercial objectives, although it may be in fields of present or potential interest to the reporting company.[1]
>
> Applied Research. Research projects which represent investigation directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes. *Note that this definition of applied research differs from the definition of basic research chiefly in terms of the objectives of the . . . company.* (Italics mine)
>
> Invention . . . aims not at the disclosure but at the practical application of a principle which may be fully or only partially apprehended. The inventor is concerned with immediate ends and normally with limited problems of materials and methods. In effect he simply directs and experiments to yield a predetermined result.[2]

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[1]The term *Basic Research* is generally used very loosely as a synonym for either *Pure* or *Fundamental Research*. Pure research is directed toward increased scientific knowledge and applies primarily to research activities in colleges, universities, and other nonprofit institutions. Because this definition does not take into account commercial goals, it has little application in industrial research.

[2]The definitions of Research and Development, Development, Basic Research, and Applied Research are quoted directly from National Science Foundation, "Trends in Funds and Personnel for Research and Development, 1953-61," *Reviews of Data in Research and Development*, NSF 62-9, No. 33, April, 1962, p. 8 and "Research and Development in American Industry, 1961," *Reviews of Data in Research and Development*, NSF 62-32, No. 36, September, 1962, p. 12. The definitions of Research, Pure Research, and Fundamental Research are quoted directly from George W. Howard, *Common Sense in Research and Development Management* (New York: Vantage Press, 1955), pp. 11-12. These three definitions are elaborations of those adopted by the Industrial Research Institute in 1948 and the Joint Research and Development Board in 1947. Invention is quoted from James Brian Quinn, *Yardsticks for Industrial Research* (New York: The Ronald Press Company, 1959), p. 4.

Another widely used term in the language of research is <u>technical service</u> or <u>technical research</u>. When this function is considered a part of the research activity it applies to taking immediate corrective action on pressing sales or manufacturing problems which might have an effect on corporate earnings.

It is obvious from the above definitions that research and development covers a variety of activities and purposes, including: research of new products and processes; improvement of existing products and processes; finding new uses of present products; solving technical problems; and expanding general knowledge. Illustrated below is an example of the way research and development activities are classified by a large chemical company:

1. Research--New Products
   Includes all investigative costs in this company's laboratory or elsewhere up to the point where the product is ready to be marketed.

2. Research--Cost Reduction
   Includes all laboratory and pilot plant work having as its objective reduction in cost of present operations.

3. Research--Maintenance of Operation
   Covers laboratory and pilot plant work on going processes under control of the manufacturing department where this work is made necessary by circumstances such as unsatisfactory quality, development of a new raw material or factory processes that are not working satisfactorily.

4. Research--Quality Improvement
   Covers laboratory and pilot plant work to improve quality of a product already on product name list.

5. Technical Service
   Includes laboratory and pilot plant work performed specifically as a service to another department within the company or for a customer or prospective customer.

6. Product Development
   Includes work to develop new uses for existing products and financial analyses of suggested new products including estimates of production costs, selling price, and required investment.

7. Manufacturing Carried on by Research
   Includes time of research personnel spent in connection with actual plant operations which are still under control of the research department.

8. Miscellaneous
   Includes all activities not covered above such as committee work, library, general research.[1]

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[1] "Accounting for Research and Development Costs," N.A.C.A. Bulletin, XXXVI (June, 1955), 1376-1377.

CHAPTER I

A GROWTH RECORD FOR A DECADE

In April 1962, the following statement was published by the National Science Foundation concerning research and development activities in the United States:

> The Record for a Decade. From 1951-52 through 1960-61, cumulative operating expenditures for research and development in the Natural sciences totaled roughly $80 billion, about four times the estimated comparable amount for the preceding 10 years. The $80 billion investment, which excluded expenditures for plant and equipment, compares in magnitude with the Federal budget for fiscal year 1961, which was also about $80 billion.[1]

Anyone who follows world developments is struck by the realization on the part of all countries that their future is largely dependent upon the advancement of their own science and technology. What is not fully realized is the rate of acceleration of science and technology.

Research and development performed in the industrial laboratories grew at a spectacular rate in the 1950's. The trend in funds used for performance of industrial research

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[1]National Science Foundation, Reviews of Data on Research and Development, NSF 62-9, p. 1. Data in this section is based primarily on material published by the National Science Foundation. Time periods for R and D expenditures are expressed in terms of hyphenated years to indicate a span of one year and to take account of the range of business, academic, and fiscal years employed by various survey respondents.

and development in the United States for the past eight years is shown in Figure 1. Research and development in dollars has approximately doubled in the past five years. This progress is similar in most industrialized countries.[1]

Figure 2 represents the trend in the Gross National Product. In current dollars, outlays for industrial research have jumped from $3.6 billion in 1953-54, to $10.5 billion in 1960-61, an increase of almost 200 percent. During the same period Gross National Product increased from $365.4 billion to $504.4 billion, an increase of about 40 percent. Compared to this growth in Gross National Product, industrial research grew five times as rapidly.

In 1960, R and D scientists and engineers employed in research laboratories in all sectors of the economy numbered approximately 387,000, compared with 223,000 in 1954.[2]

The total number of employed in company laboratories in 1960 was about 780,000, compared to a total of 200,000 in 1950. The total labor force in the United States increased by only one-eighth during the same period.[3]

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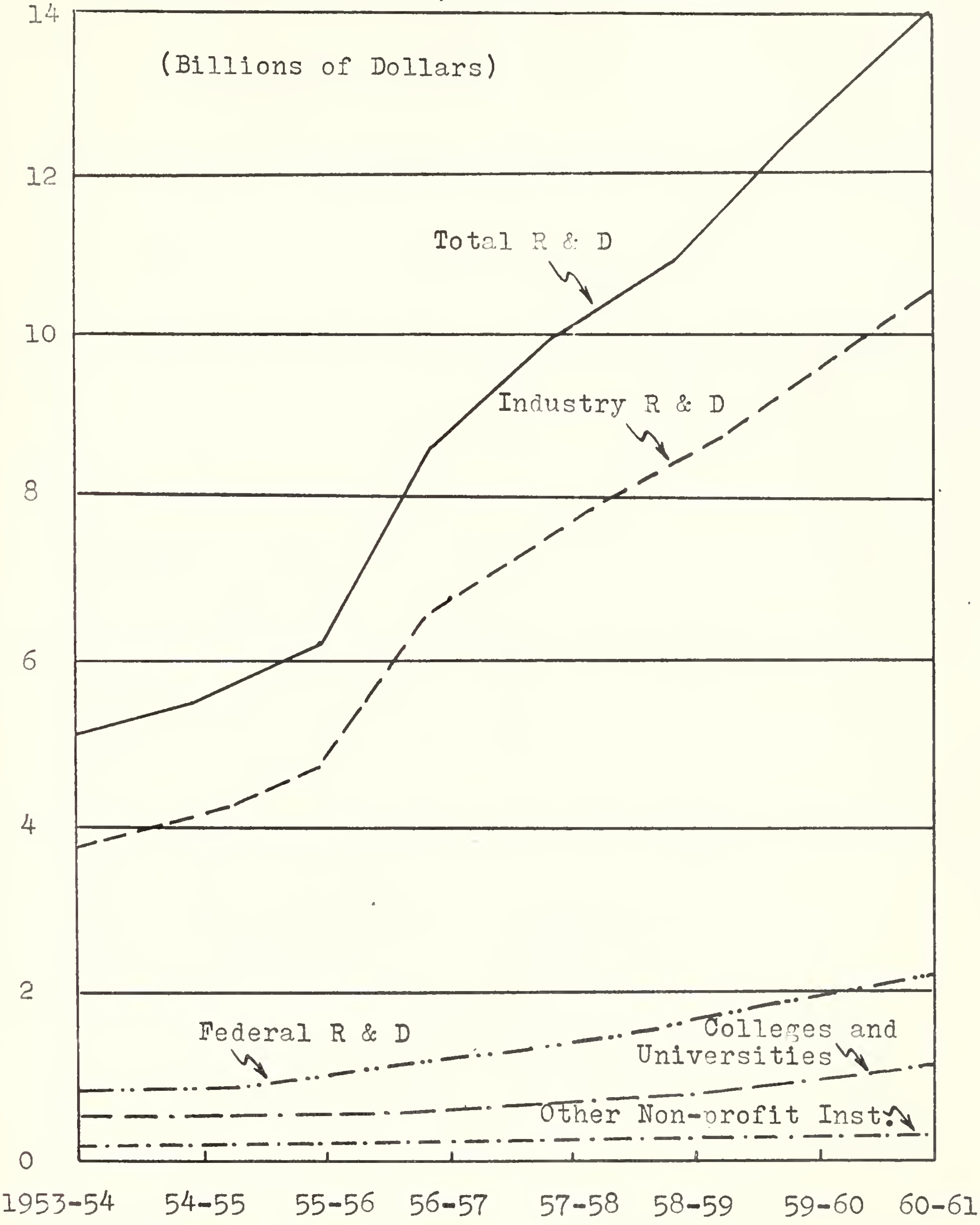
[1]Alan T. Waterman, National Science Foundation, Eleventh Annual Report for the Fiscal Year Ended June 30, 1961 (Washington: U. S. Government Printing Office, 1961), p. IX.

[2]National Science Foundation, Reviews of Data on Research and Development, NSF 62-9, p. 6.

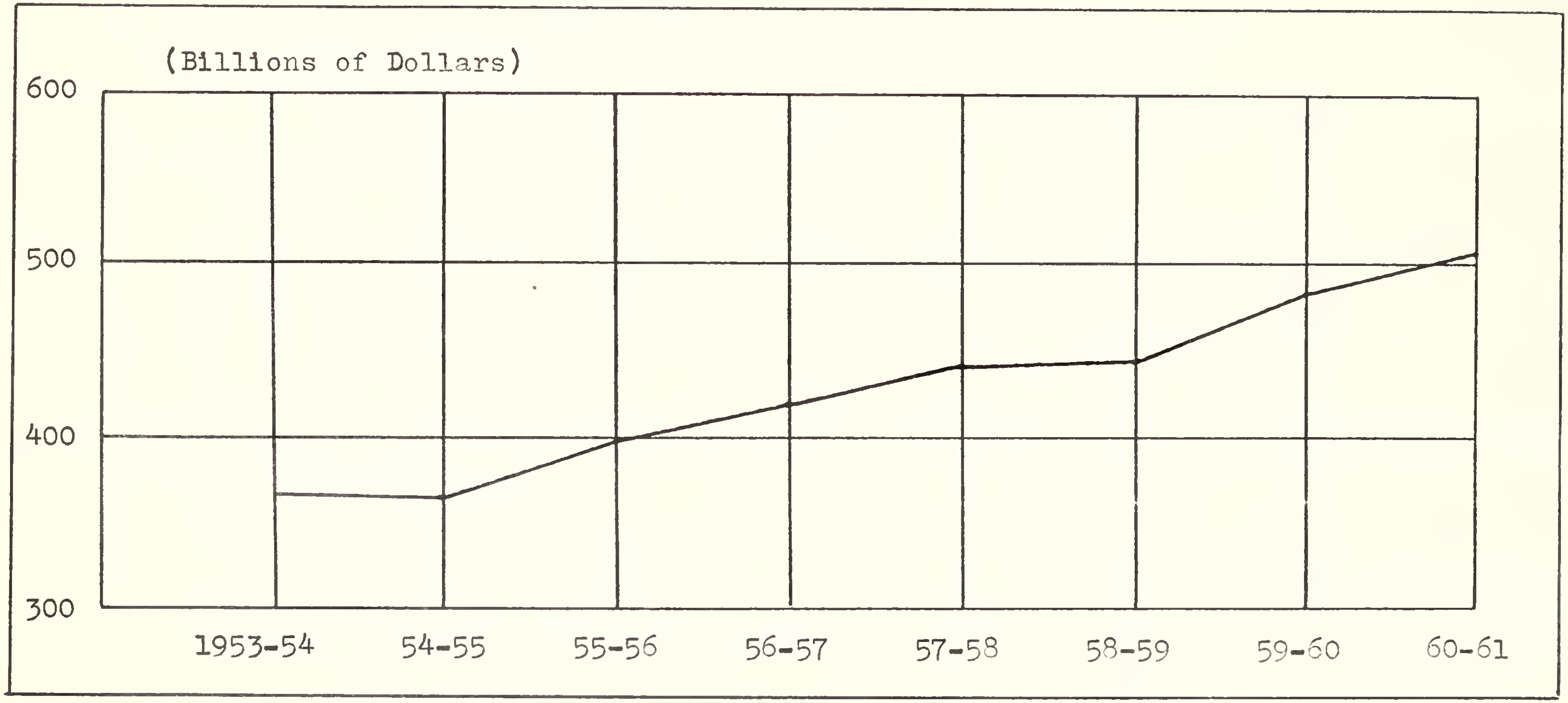
[3]Yale Brozen, "The Future of Industrial Research," The Journal of Business of the University of Chicago, XXXIV (October, 1961), 434.

Figure 1.--Expenditure of Funds for Research and Development, by Sector, 1953-54 -- 1960-61.[a]



[a]Data obtained from: National Science Foundation, "Trends in Funds and Personnel for Research and Development 1953-61," Reviews of Data on Research and Development, NSF 62-9, No. 33, April 1962 (Washington: U. S. Government Printing Office, 1962), p. 2.

Figure 2.--Trends in the Gross National Product (GNP), 1953-54 -- 1960-61[a]



[a]Data obtained from: National Science Foundation, "Trends in Funds and Personnel for Research and Development, 1953-61," Reviews of Data on Research and Development, NSF 62-9, No. 33, April 1962 (Washington: U. S. Government Printing Office, 1962), p. 7.

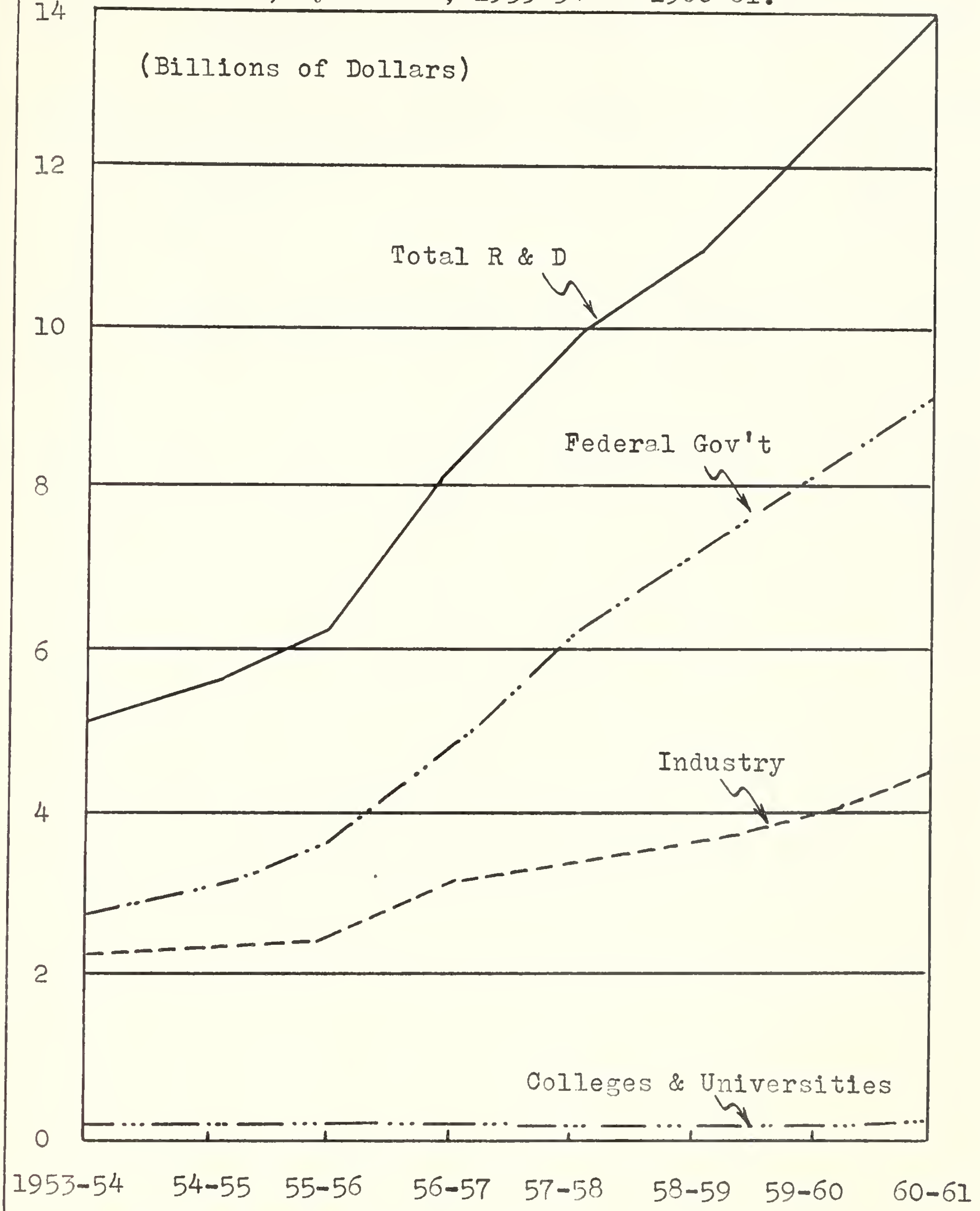
Of the total funds spent in 1960-61, industry was the largest spender for R and D, and the Federal government was the largest provider of funds as indicated in Figure 3. In the latter year industry spent $10.5 billion of the total $14 billion spent on R and D, or approximately 75 percent of the total. The 75 percent expenditure by industry has been the general pattern for the past decade, although the National Science Foundation expects industrial performance to go higher in the next few years.

Although the total expenditures for research and development are still rising, R and D clearly represents only a small fraction of our total annual expenditure and is only a third of what industry spends for new plant and equipment. (Table 1).

The national totals of research and development are separately classified according to categories (basic, applied, and development) in Table 2. The three components of R and D have remained fairly constant in recent years. Expenditures for development have been about 70 percent of the total, applied research expenditures have accounted for slightly less than 25 percent, and basic research has been about 5 percent of the total.

Figure 4 shows some striking differences with respect to the transfer of funds. The Federal government and industry spent the greatest proportion of funds in the performance of development, which is consistent with the emphasis on space

Figure 3.--Sources of Funds used for Research and Development, by Sector, 1953-54 -- 1960-61.[a]



[a]Data obtained from: National Science Foundation, "Trends in Funds and Personnel for Research and Development, 1953-61," Reviews of Data on Research and Development, NSF 62-9, No. 33, April 1962 (Washington: U. S. Government Printing Office, 1962), p. 2.

TABLE 1.--Business Expenditures for New Plant and Equipment and Industrial Research and Development Performed, 1929-70.[a]

	EXPENDITURES FOR NEW PLANT AND EQUIPMENT		INDUSTRIAL R & D			PLANT, EQUIPMENT, AND R & D INVESTMENT
Year	Billions of $	% of GNP	Billions of $	% of GNP	% of Investment	% of GNP
1929	$ 9.5	9.1	$ 0.18	0.17	1.8	9.3
1948	22.1	8.5	1.9	.7	7.6	9.2
1951	25.6	7.8	2.5	.8	8.9	8.6
1960	35.7	7.1	9.5	1.9	21.0	9.0
1970 (projected)	$50	6.7	$18	2.4	27	9.1

[a]Source of data: Yale Brozen, "The Future of Industrial Research," The Journal of Business of the University of Chicago, XXXIV (October, 1961), 437.

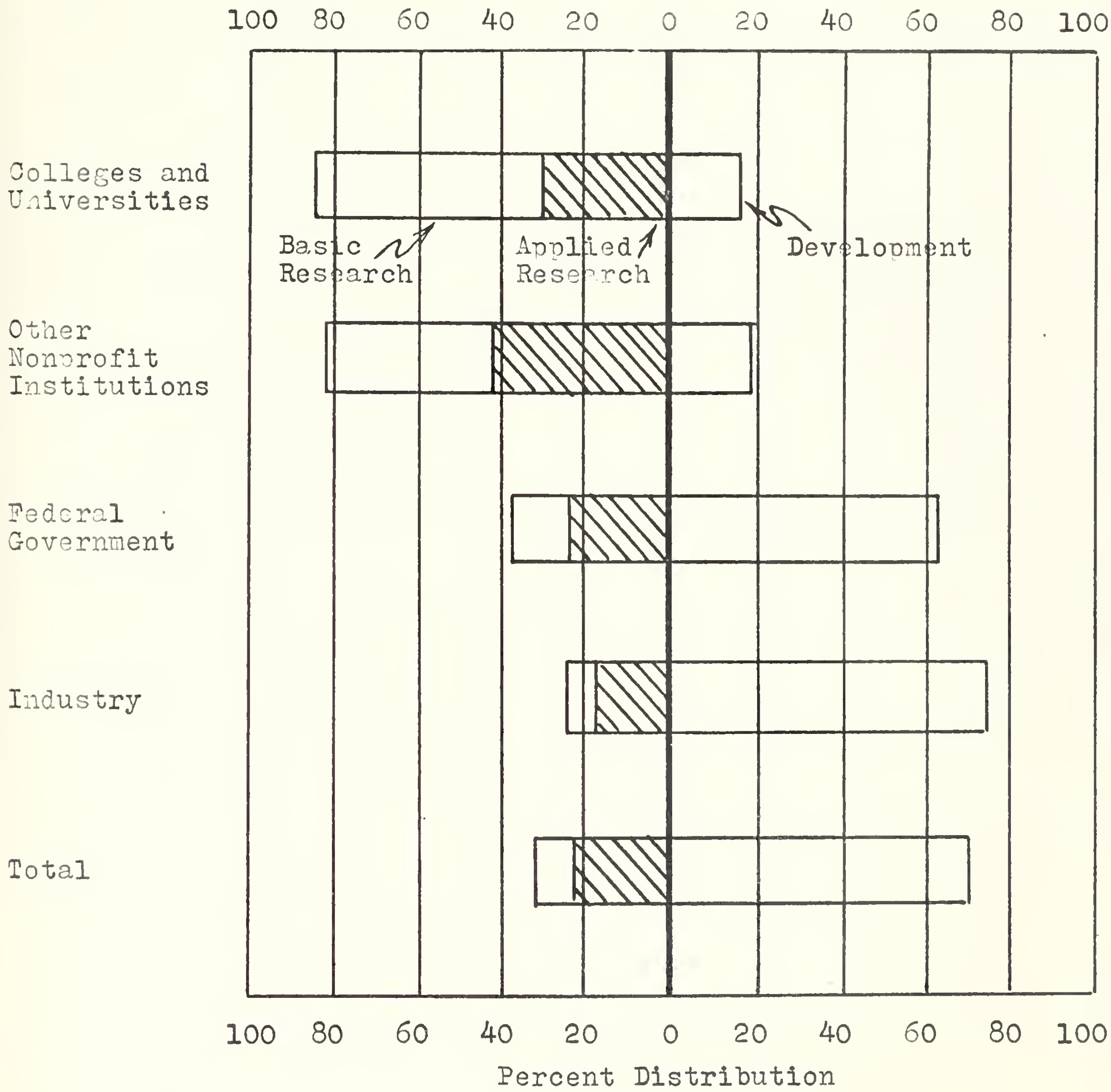
TABLE 2.--Funds Used in the Performance of Basic Research, Applied Research, and Development, 1959-60.[b]

(millions of dollars)

Sector	Amount			
	Total R & D	Basic	Applied	Development
Total	$12,620	$1,150	$2,850	$8,620
Federal Government	1,830	220	460	1,150
Industry	9,550	345	1,955	7,250
Colleges and universities	1,000	500	330	170
Other nonprofit institutions	240	85	105	50

[b]Source of data: National Science Foundation, Review of Data on Research and Development, NSF 62-9, April 1962 (Washington: U. S. Government Printing Office), p. 5.

Figure 4.--Basic Research, Applied Research, and Development--Percent Distribution of Funds Used in Performance, by Sector, 1959-60.[a]



[a]Data obtained from: National Science Foundation, "Trends in Funds and Personnel for Research and Development 1953-61," Reviews of Data on Research and Development, NSF 62-9, No. 33, April 1962 (Washington: U. S. Government Printing Office, 1962), p. 6.

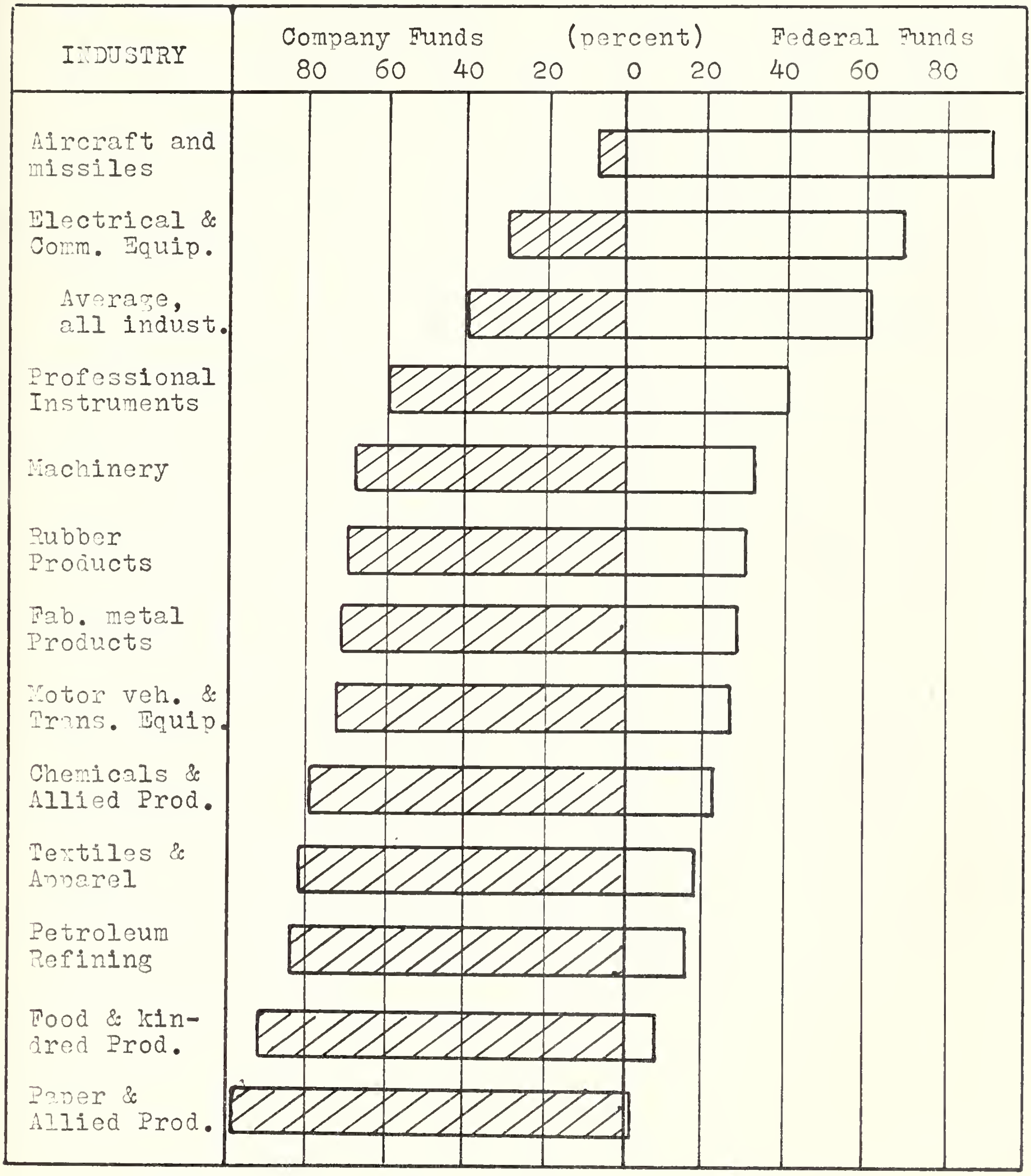
projects and national security. Basic research occupies the foremost position in colleges and universities.

Figure 5 indicates the percentage distribution of funds for performance of R and D by industry in 1961. As the chart indicates, industry contributed a substantial percentage of the national pool of funds for R and D. It is quite obvious that some industries are more research minded than others, and in any industry some companies are more research oriented than others. It is of interest to note that in 1961, the $3.6 billion for Federal projects in the aircraft and missiles industry and the $1.6 billion in the electrical equipment and communications industry comprised 80 percent of the federally financed industrial research and development.

Although it is obvious from the above discussion that the Federal government is financing a considerable amount of research and development, the bulk of these expenditures are in space and defense oriented industries. However, the R and D performance of the majority of industries was financed primarily from company funds (Figure 5). Industries that financed 90 percent or more of their R and D projects with company funds were paper and allied products; stone, clay, and glass products, food and kindred products; primary metals, and petroleum refining and extraction.

Many of the managerial problems in industrial research stem from the rapid growth rate of R and D during

Figure 5.--Percentage Distribution of Funds for Performance of Research and Development, by Industry and Source, 1961.[a]



[a]Data obtained from: National Science Foundation, "Research and Development in American Industry, 1961," Reviews of Data on Research and Development, NSF 62-32, No. 36, September 1962 (Washington: U. S. Government Printing Office, 1962), p. 7.

the past decade. Most companies boost their annual expenditures for research by substantial amounts and it is not at all unusual for some companies to increase annual expenditures by as much as twenty percent per year. However, the management of many companies is becoming concerned about the amount being spent for product development which does not pay off in the market place. Because profits are not in line with the amount of money expended for research, managements of many companies are looking toward improved methods of research management.

In an article devoted to the problem of rapid growth of industrial research and development, William L. Swager, Assistant Manager, Department of Economics of the Battelle Memorial Institute, sums up the present research situation by saying:

> Any living organism, organization, or group activity tends to get out of control if it grows too rapidly. So it is with scientific research. Research in its broadest sense covers the entire spectrum of technical activities--research, development, and engineering. The rapid growth during the past twenty-five years of this continuum of activity called research which defies further precise subdefinitions has been considered by many to be far from orderly and controlled. Because of the rate of growth and for other reasons, many executives consider research to be a serious managerial problem.[1]

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[1] William L. Swager, "Improving the Management of Research," Business Horizons, II (Winter, 1959), 42.

CHAPTER II

PLANNING FOR RESEARCH

> The benefits of long-range planning of all corporate activities, including a total corporate or "master" plan, are widely recognized. Most companies of any size now have at least a five-year plan. Long-range planning helps insure continuity of profits and permits timely corrective action where a look into the future shows unfavorable situations developing. It permits capitalization on opportunities provided by changing technological, market, and competitive trends which are difficult to appreciate on a year-to-year basis. If a company does not have a long-range program for its research, as well as for other activities, it incurs the hazard of losing position because its competitor does have such a plan.[1]

Long Range Corporate Planning

All research is not good research. A company should only support a research program if it provides the most effective and most inexpensive method of reaching company goals. Thus over-all, both short and long-term, company objectives will help guide the research efforts of a company. Far too frequently the research program of a company will drift toward the studies which intrigue a particular scientist,

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[1] William E. Hill and Charles H. Granger, "Management Objectives and Basis for Evaluation," Handbook of Industrial Research Management, ed. Carl Heyel, p. 33.

or toward pet projects of some top executive. These projects are often costly and do not bear any resemblance to the needs and plans of the company.

Henri Fayol at the turn of the century expressed the need for formulation of long-range plans and the establishment of company goals in his General and Industrial Management.

> The maxim, "managing means looking ahead," gives some idea of the importance attached to planning in the business world, and it is true that if foresight is not the whole of management at least it is an essential part of it. To forsee, . . . means both to assess the future and make provision for it; . . .[1]

But why do some managers fail to establish company objectives which are meaningful guides for proper research planning? One reason is that goals are often defined so strictly that potential research programs are curtailed due to inflexibility. And in other cases goals are so broad that researchers have no guidelines to adhere to and are thus ineffective, to say the least. Management must define what research is to contribute to the organization and how it is to go about it.

In addition, management must establish a proper balance between long-term and short-term goals. Too frequently top management thinks only in terms of the short-run competitive market and neglects the long-range outlook. Professor

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[1] Henri Fayol, General and Industrial Management (New York: Putman Publishing Corp., 1949), pp. 43-52 quoted in Harold Koontz and Cyril O'Donnell, Readings in Management (New York: McGraw-Hill Book Co., Inc., 1959), p. 308.

James Brian Quinn of Dartmouth College, who recently conducted an extensive study of industrial research and development, has this to say about the balance between short-term and long-range goals:

> The longer-term, perhaps more important, opportunities and dangers are forgotten under the day-to-day pressures of market competition. Although development work can sometimes solve problems which arise from short-term operating difficulties, applied and fundamental research can only support objectives which remain stable for three to seven years, or until their results can be exploited. Hence, top management must provide meaningful, long-term objectives . . .[1]

Management expects the R and D department to do an excellent job in the area in which it has determined the department should be concerned. If R and D comes up without a top notch job in some other area, management will probably be unimpressed. This gets back to objectives. Some companies have objectives for R and D, and others do not. Small companies getting started may not have objectives. There is a strong feeling that a growing company should be dynamic and free from interference. However, after a company has grown there should be a stabilizing influence.

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[1]James Brian Quinn, "Long-Range Planning of Industrial Research," Harvard Business Review, XXXIX (July-August, 1961), 89. The above quote and subsequent comments in this chapter regarding the planning of industrial research are largely the work of James Brian Quinn, Professor of Business Administration, Dartmouth College. Professor Quinn has conducted extensive surveys of current industrial research practices. The two major sources of Quinn's used in this chapter include the reference above and Quinn, "Top Management Guides for Research Planning," Technological Planning on the Corporate Level, ed. James R. Bright (Boston: Harvard University, 1962), pp. 169-200.

Corporate Objectives

> It is essential that there be . . . total company objectives of such scope and vision as to provide meaningful guidance to product research programs . . .[1]

In order to establish a firm set of corporate objectives which stimulate research in the proper direction, certain long-range planning problems must be considered.

The company must first decide in what kind of business it wants to be. Here the company must consider the kinds of markets in which it will compete, and the functions its products must perform for the customer. For example, an electronics company should decide whether it wants to be in the transmission business only, or whether it should consider many phases of the industry, such as consumer appliances, industrial controls, information processing devices, etc. Obviously a "broad line" company will have different goals, and therefore a different research program from a "narrow line" company. Companies with top-ranking laboratories, such as Bell Laboratories, have taken a non-traditional approach to research and have been responsible for startling advances in industrial technology.

A second problem which must be faced in formulating objectives is the rate of growth of the company. A company

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[1] Robert M. Bowie, "Aligning Product Research Progress with Total Company Objectives," Research Management, V (January, 1962), 31.

must determine its growth rate dependent upon its particular limitations. These limitations include personnel, resources, and markets. Too rapid a growth rate may often be as disastrous as too little. Companies have experienced a rapid growth on the basis of a new discovery and then collapsed because of insufficient capital and poor organization to support itself. Each company must determine its limitations and adjust growth rate accordingly.

A third factor concerning corporate objectives is the overall direction of intended growth. A decision must be made as to whether development should be vertically within its present market area or horizontally into new areas and markets. In other words, should the company be "narrow line" or "broad line" in its research and development efforts? The decision as to the type of growth intended vastly affects the scope of the research program.

A fourth consideration is to what extent growth is to be dependent on research. Research, after all, is only one of the many methods of company expansion. If growth through research is intended, the organization and planning of the company must be adjusted in accordance with this policy. Factors which must be considered are (1) that the return on investment may be longer, (2) operating departments must be technically oriented to be ready to follow up on research achievements as they appear, and (3) capital planning must be flexible enough to provide funds for long investment cycles

which are oftentimes characteristic of research activities.

Another factor to be considered in determining corporate objectives is the desired "image" of the company. Often a company desires to appear progressive in order to attract top flight technical people, to increase confidence in its products, and in general to present an image of technical progressiveness.[1]

The image of a company has through research been carried to extremes in some cases. There are companies in existence today which are involved in research not to produce new or improved products or processes, but to maintain the status quo, or to "spend big" for research, because it represents a status symbol. There are other corporations which have built extravagant laboratories primarily for the benefit of investors.[2]

As a last consideration, most companies have a natural growth pattern for their future development. Because of special patent situations, special know-how, distribution advantages, or other unique advantages, a company may have a jump on competitors. A company should seriously consider these natural advantages in establishing corporate goals. For example, in the case of Litton Industries, although the

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[1] Cf., Quinn, "Long Range Planning of Industrial Research," Harvard Business Review, pp. 89-90.

[2] Nelles, loc. cit.

company had not been in the office machine business, a special background in electronics made entry into the electronic computer field a natural growth opportunity.

The considerations concerning objectives, or perhaps more properly classified as targets or goals which have just been described, concern the over-all business objectives. A decision concerning these by top management establishes the broad nature of the enterprise, and the general direction in which it is going to move. These objectives should be more or less permanent and should stand for a number of years.

Problems in Setting Objectives

Although it is apparent for proper research planning that objectives must be established, it is also apparent that mistakes are made in dealing with objectives. For example, many companies change their objectives to meet urgent competitive pressures. In many instances the organization becomes accustomed to the management attitude of "profit now, objective later." In other words, research becomes a short-term service activity without a supporting long-range plan. In other cases objectives are too broad and general in nature. Such over-generalized goals are couched in terms such as "growing as rapidly as possible, diversification in any profitable field, maximize profits," etc. Objectives of this type do not stimulate research in the proper direction. On the other hand, corporate objectives can be too specific.

Professor Quinn describes objectives of this type as follows:

> Some organizationally immature operations overplan research by setting goals in too great detail. Such goals take either of two forms: (a) specific materials, pieces of hardware, test measurements, components, etc., demanded by operating groups, or (b) step-by-step experimental goals. Such goals occur when operating or staff groups dominate the research function. The obvious result is that research is constrained in its approaches to problems since it is told how to do the job, and not what is to be done.[1]

All organizations must look ahead and must set goals for long-range planning. On the issue of short-term orientation of decision and plans a chairman of the board of one large corporation had this to say:

> Any damn fool can make a profit for a month--or even a year--by gutting the organization's future. Top management's job is to keep the company "future oriented." We try to do this by using a complex of long-term management controls. We play down the use of current profits and return standards in any rigid sense. And we purposely use intuitive judgments concerning how well each operating unit is building its organization and technology to meet future demands. So far we have resisted taking on board members from banks and financial houses because we think such people over emphasize current profits at the expense of future strength.[2]

The point that should be emphasized is that for maximum benefit to the corporation objectives should be long-term in nature, based on what the company wants to be

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[1] James Brian Quinn, "Top Management Guides for Research Planning," Technological Planning on the Corporate Level, ed. James R. Bright (Boston: Harvard University, 1962), p. 173.

[2] Ibid., pp. 173-174.

in the next ten, twenty, or thirty years, and how they plan to grow. Without proper guidance from objectives, programs will tend to drift toward studies that fascinate researchers, toward the pet projects of top executives, toward sales service, or other short-term functions with little regard to the long-range outlook.

Forecasting

Having established the basic corporate objectives, the company should look ahead to the forecasts of future product needs and trends. This is an important prerequisite before detailed plans are arranged for research implementation. What types of forecasts and trends are important?

Forecasts may generally be broken down into three separate categories for long-range planning purposes: economic, sociological, and technological.[1] Considerations and requirements of the individual forecasts will be discussed in the following sections.

Economic Forecasts

Long-range research planning should be based on general trends in the economic area. The purpose generally associated with the economic forecast is to ascertain to what extent the economic climate of the future will allow

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[1] Quinn, "Long-Range Planning of Industrial Research," Harvard Business Review, p. 91.

introduction of certain types of technology. In general, this type of forecast will be an expression of the probability of moving into certain areas.

Sociological Forecasts

Although this type of forecasting is somewhat less common than economic forecasts, it is gaining in emphasis in many large companies. This type of forecasting emphasizes the ways various social and institutional factors may impinge on a company's future in research planning. Factors which should be considered include the nation's demographic structure, such as the size, location, age, and economic distribution of the population five, ten, or fifteen years in the future; the role of the government in the economy; the general international, political, market, and monetary situation; and the availability of skilled labor and trained scientists. Forecasts of this nature have led some companies into research programs which more limited considerations would have not indicated. Demographic factors have led scientists into such fields as geriatrics, synthetic foods, recovery of water from the sea, various exotic sources of food, and chemical methods of contraception.

> Some companies are beginning to orient some of their technological thinking toward arms control. This move is based on a changing U. S. and international attitude toward such activities, as well as the growing potential of a multi-

billion-dollar business in arms control devices.[1]

In the field of sociological forecasting many companies are enlisting the professional services of consultants and other groups such as the Long Range Planning Service of Stanford Research Institute. The most important factor is that management must not be waylayed by traditional approaches to research planning. They must take a broad look at technological opportunities for maximum benefits.

Technological Forecasts

The factors to be considered in technological forecasting are generally in the scientific area, the company's present and potential customers, and company competitors. Primary managerial considerations in this area include the kind of organizations which will be useful in predicting technological change, the information necessary for planning, and the problems in forecasting threats and opportunities in the scientific field.

In forecasting the general scientific area, some companies have developed grids of all the basic sciences which might potentially impinge on operations. Each scientific field is reviewed on two bases. First, the company investigates whether the science is showing promise of rapid development, is making rapid contributions, or is comparatively

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[1] Quinn, "Top Management Guides for Research Planning," Technological Planning on the Corporate Level, pp. 183-184.

dormant. Secondly, the company evaluates whether the science is developing in the direction associated with the company's goals. With this information the company determines whether or not an increased emphasis is required in the fundamental program of research and development.

Other companies select specific areas for study which top management or research directors feel might eventually infringe on company projects.

Some companies have projected the future state of the art in technological fields by using forecasts of critical sociological factors whose change will create the need for technology. With this information the forecaster attempts to predict future technical needs in a particular field.

Still other companies use a more informal method of forecasting technological changes. For example, many research directors say that they know what all competitors are working on in their research labs.[1]

One of the most important forecasting areas is the investigation and prediction of present and potential customers of the company. Market researchers routinely look ahead three to five years, but often get bogged down in present needs.

In Quinn's two-year survey of thirty-five major companies in the chemical, electrical, electronics, basic

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[1] Ibid., p. 180.

metals, and pharmaceutical industries, some specific forecasting techniques were found. Three of these which he mentioned in a conference at the Harvard Business School in 1961, and which could propel a company into new or expanded markets are:

> A glass company considers those properties of its product (glass) which are unique into it, i.e., exceptional tensile strength, chemical resistance, translucency, ductility, etc. It then seeks to identify present and potential markets in which consideration of one or more such properties is a dominant factor. Its applied research program then seeks glasses with intensified properties needed to meet recognized market needs. Its fundamental program seeks primarily to further isolate and understand the properties of various glasses.[1]
>
> A chemical company invites its customer's technical and management personnel to seminars at which they discuss their developing scientific problems and learn about the sponsor's own current research programs. The company then tries to meet defined needs through its own R and D program and through cooperative research with customers.
>
> . . . .
>
> One company has a long-range . . . group . . . charged with long-range thinking in customer and potential customer companies. . . . They try to meet future technical needs--three to ten years ahead. The group claims to be able to spot needs and opportunities that customers themselves cannot see. . . .[2]

In general, proper forecasting outlines the potential threats and opportunities for long-range planning for the research program. Present research is compared with forecasted needs; gaps are noted and the key facts associated with these gaps are identified; present programs are reviewed to see

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[1] *Ibid.*, p. 182. [2] *Ibid.*, p. 181.

which programs are being worked on and if progress is being made; and past experience is considered in determining the probability of success for projected programs. With this past history and future trends and forecasts, planners can look ahead to what is needed for future growth.

Corporate Profit Objectives

> A corporation's principal responsibility is to make a return on investment on the part of its stockholders; to do this they must produce products . . . at a profit. Inasmuch as competition is continuously raising its ugly head to minimize these profits, steps must be taken to counteract this. The only dependable recourse in most cases is . . . a research program. . . . The gain from research . . . is a profitable business.[1]

Having set the basic corporate objectives and having estimated the technological, economic, and sociological trends of the future, management must then determine corporate profit objectives. Return on investment and growth in earnings are undoubtedly the most crucial quantitative profit standards a company has.

The result of profit planning should be the preparation of a five to ten-year corporate plan involving sales, profits, and capital requirements, both for existing and new products. In this area there are four fundamental steps:

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[1] Arthur R. Lytle, "Can Successful Research Be Directed?" Proceedings of the Twelfth National Conference on the Administration of Research (University Park: The Pennsylvania State University Press, 1959), p. 61.

1. Step one involves an analysis of the company's operating record to date with respect to profitability, growth of cash flow, earnings per share, and other measures in comparison with other companies and the total industry. Other performance yardsticks might include growth of sales, profits, cash flow, and earnings per share as compared with other companies.

2. Step number two involves establishing standards for future profits. Standards will vary depending upon the overall company goals, and the company's relative position in the industry. For example, Company "A" in Figure 6 has the objective of maintaining an attractive profit record, whereas Company "B" should at least be attempting to raise its return on investment to the average of the industry, or above. The industry average can be an important factor, however, and sometimes it can be extremely misleading. Operating ratios of companies within an industry may vary widely because of the various types and sizes of companies within an industry.

3. The third step in planning future profits is a five- or ten-year projection of sales and profits, together with the projected capital investment requirements. These projections should be based on the various forecasts which were discussed in the previous section, and the results of market research.

4. The last step is a measurement of the need of new products and processes. This is obtained by taking the

Figure 6.--Pretax Return on Investment of Two Companies compared with all Manufacturing Companies.[a]

[a]Source: William E. Hill and Charles H. Granger, "Management Objectives and Bases for Evaluation," Handbook of Industrial Research Management, ed. Carl Heyel (New York: Reinhold Publishing Corp., 1959), Figure 4, p. 42.

difference between the projection of present products in Step 3, and what the company is doing now. It is obvious that financial resources of the company will determine the feasibility of the objectives.[1]

Research Strategy

The final consideration by top management in research planning is to develop an overall business strategy which research is to help support. This strategy supports the company growth and profit objectives, is based on future market and customer trends, and determines how the company can best meet its objectives in light of competition, opposing outside pressures, and its own limited resources. The basis behind a strategic plan is to emphasize company strengths, and at the same time negate to the maximum extent strengths of the competitor. Obviously, no company is pre-eminent in all fields. Because of limited resources, each company must expose itself to some risks and pass up some opportunities.

As a starting point a company must minimize serious technological threats which will affect its existence. So as a start, a company should look toward the technical area which must be protected at all costs. In these areas the company must strongly emphasize research efforts because of pure competitive survival.

Next in line in formulating a strategic plan is a managerial determination and analysis of the areas of company strengths and weaknesses. Such considerations will determine where a company's program should be the strongest.

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[1]Hill and Granger, loc. cit., pp. 39-43.

> Unless a company adequately assesses its particular strengths and weaknesses and develops its resources properly around these, it will eventually be a "me too" operation, unsatisfactorily trying simply to meet competition on all fronts.[1]

The strategic plan must also insure that sudden advances by other companies will not catch the company unaware and thus overlook exceptional opportunities in new technological areas.

There are many problems which management faces in developing a research strategy. Many executives do not recognize that growth through research must be backed by entirely different kinds of financial and organizational commitments than more conventional market development or acquisition strategies.

> The research approach requires: (1) that management think in terms of a five to seven-year payback period instead of the two to four-year period common to other investments, (2) that management be willing to make research investments with less certain information and a potentially higher risk than normal operating investments, (3) that a flexible long-term capital plan be developed to meet the unpredictable investment spurts and long investment cycles characteristic of research, (4) that operating departments be more technically oriented and highly coordinated to achieve maximum benefit from research technology, and (5) that the over-all organization to be planned to grow flexibly from within rather than through acquisition of entire experienced operating units from outside.[2]

Another problem in strategic planning is the frequent attitude by management that the company should continue to do things as they always have been done. This leads to problems such as:

1. Companies tend to balance their programs to match present product lines, sales, or investment patterns rather than building programs to meet maximum technological threats or to take advantage of opportunities.

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[1]Quinn, "Top Management Guides for Research Planning," Technological Planning on the Corporate Level, p. 189.

[2]Ibid., p. 189.

2. Few companies tend to balance their investment risks by purposely taking on extremely high risk projects. Instead they tend to research traditional products, using standard approaches. Although scientists frequently would like to take risks, they are too often constrained by management.

3. Companies generally define their research strategies too narrowly and thus do not define themselves adequately against the eventual costs of short-term technical orientation. Too few companies have really faced up to supporting the truly long-term research which is needed to keep U. S. industry in the technological forefront.[1]

William E. Hill and Charles H. Granger list five principal phases in the development of an over-all long-range research strategy keyed to company objectives. These principles have been followed with considerable success by both large and small companies.

Phase I.--Analyze the past record and present status of research activities, independently and in relation to industry practices, in terms which are of maximum utility in relating research to corporate goals. Five steps are necessary.

1. Prepare a history of total expenditures for research activities in dollars, man days, dollars per unit of company volume, percent of sales, percent of profit, etc. Such data will establish historical over-all parameters of the research activity.

2. Analyze historical project activities in dollars and man days by class of research (basic, applied, development), by application (quality improvement, new products, cost reduction, etc.), by broad product categories, by markets involved, and by

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[1] Ibid., p. 190.

research subdepartments.

3. Tabulate the inter-relationships among the major elements in the above step.

4. Analyze quantitatively the research activities of competitors in the industry.

5. Summarize qualitatively the direction and nature of competitive research activities by broad product area and class of research.

The results of Phase I summarize the company's historical research activity and relates it to industry and competitor practices.

Phase II.--Translate corporate objectives into tangible research objectives and opportunities in the present products and processes of the company. The object of this phase is to determine the extent and application of research needs for each present product. Four principal steps are involved:

1. Establish the R and D opportunities and requirements based upon the corporate objectives of volume, volume increase, share of market, projected profit, projected investments, etc.

2. Determine future functional requirements for products which are being produced at present.

3. Determine the opportunities and needs of competitors.

4. Determine company opportunities based on existing research resources and know-how. This will point out the products which are most susceptible to cost reduction improvement or broadening of product lines.

This phase will show the relative opportunity for research activities within product areas.

Phase III.--Devise a program based on corporate objectives and other opportunities in the present business.

1. Summarize the significant trend in the product areas involved.

2. Determine by product area the degree to which basic, applied, and development research should be exploited.

3. Identify major areas to achieve corporate objectives.

4. Allocate funds to areas in light of opportunities and promise of return on investment.

Phase IV.--Program research leading to new products and processes. Here the steps are largely dependent on the corporate plan for evolution into new fields.

1. Determine the extent of new business required in the corporate plan.

2. Examine proposed new product areas, considering corporate skills, position of the company in the industry, limitations in regard to resources, and competitive position in the proposed markets.

3. Determine by means of forecasts of volume, profit, and functional requirements the way to profitable operations in the new business.

4. Provide for commercialization of the new product or process.

Phase V.--Develop supporting functional programs.

1. Manpower requirements must be determined.

2. Plant facility requirements must be established.

3. Future evolution of the organizational structure

must be considered.

4. A continuing research-planning activity must be formalized in order periodically to update the plan.[1]

The preceding discussion shows a definite relationship between corporate objectives and long-range research planning. Today with so much emphasis on research, the two are inseparable. The benefits of long-range planning of all corporate activities are widely recognized. In the case of research and development a well planned strategy will permit capitalization on opportunities provided by changing technology, competitive trends, and projected forecasts which might be difficult to appreciate on a short-term basis. Aside from planned research directed at cost reduction, greater productivity, and high-margin on new or improved products, other advantages are to be gained from a planned research program. Among these might be included (1) better direction of research activities, (2) a better management understanding of the research program, and (3) an educational value to all activities.

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[1] Hill and Granger, loc. cit., pp. 47-57.

CHAPTER III

THE RESEARCH PROJECT

> Proper selection of research projects is the key to research success. Unless researchers are working on the right problems, even the most outstanding research personnel, motivated, organized, and controlled in the best possible fashion, will not make a maximum contribution to the sponsoring activity.[1]

Planning for the Research Project

There are a number of considerations which must enter into research project planning.

1. Does the project fit the interests and needs of the company? There must be an integration of projects and company objectives.

2. Will the results be useful to the company? There must be an appraisal of eventual use, adequate profit margin, and cost estimate. Market research must determine the probable scale of future operations, capital investments, and new plant facilities.

3. A measure of the impact of new products on existing products must be estimated. Sales personnel can provide information as to the influence of new or replacement

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[1] James Brian Quinn, Yardsticks for Industrial Research (New York: The Ronald Press Co., 1959), p. 169.

items on present products.

4. A check should be made concerning legal and health restrictions on proposed products.

5. Patents may prove to be troublesome.

6. Estimates of total efforts in terms of time, manpower, and facilities should be made. Research and development for a small company often may prove to be too ambitious.[1]

In establishing projects the following objectives of industrial research must be kept in mind:

1. To reduce a company's capital and operating costs.

2. To help the company provide high quality products and technical assistance at a level which will maintain, or better still improve, its competitive position.

3. To provide the company with new opportunities for attractive capital investments and new markets for new or existing products.[2]

Research management must not feel that a company supports a research activity with the hope that _something useful might_ come from the laboratory. It should look upon itself as an integral part of the organization with the aim of producing technology which will allow the company to operate and grow.

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[1]W. A. Lazier, "Planning the Research Project," _Proceedings of the Sixth Annual Conference on the Administration of Research_ (Atlanta: Georgia Institute of Technology, Engineering Experiment Station, 1953), p. 61.

[2]Asbury, _loc. cit._, p. 183.

Of primary importance in selecting research projects is to make sure that the research manager understands company operations, corporate objectives, and plans for the future. He must have a knowledge of capital limitations and the relative availability of funds for the expansion of company operations. There must be a clear understanding between management and research as to the method by which research is to serve the aims of the company. The kind of information that research management needs is best answered by questions like:

> Is the main purpose to be served by research the protection of existing earnings from existing products and processes?
>
> Does the company wish to reach beyond its present competitive position and establish clear pre-eminence in its existing field?
>
> Is competition forcing a search for new products and processes?
>
> Or is the goal to find a new source of earnings through a broadened or altered investment base?[1]

Having the basic aims of the company, then the research director can formulate plans and decide upon projects based upon the corporate objectives and the desires of top management. However, even with known company policies, the research director faces problems which ultimately must be correlated with company policy. Howard S. Turner lists four

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[1]Howard S. Turner, "How Much Should a Company Spend on Research?" Harvard Business Review, XXXII (May-June, 1954), 103.

facts which are frequently faced by research directors when making decisions on projects to be undertaken.

1. The field selected by management may already have been extensively exploited by the research teams of other companies. In this case, the research director may conclude it would be cheaper to purchase and adopt the results of research completed by others than to risk large outlays in the hope of novel discoveries in a well-worked field.

2. Or, though the proposed new field is not overcrowded, the technology involved may make it particularly resistant to experimental development. If this is the case, the research director will warn his management of the very large and continuing outlays that may be required to get useful results.

3. Attractive unit costs for some developments can only be projected for a quite large initial plant. Others may require acceptance of a substantial financial risk in designing such a plant from experience with the usual experimental facilities. Alternatively, there will be the unusually heavy development costs that go with the larger pilot plant employed to minimize the risks of scale-up.

4. Finally, a dominating variable that influences the annual cost of any research effort will be the rate of speed at which management wishes the work to proceed.[1]

When top research executives are properly informed of the over-all operations of the concern, both inside and outside the organization, then the research organization is in a position for establishing research projects. W. C. Asbury suggests three major phases in the establishment of research projects:

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[1] *Ibid.*, p. 103.

1. Obtaining ideas and developing concrete proposals.

2. Evaluating the ideas and projects.

3. Final selection of those projects which have met the requirements and have the best chances of economic success.[1]

There is no "best" source for ideas and proposals for new products and processes. Many companies regard their sales force as the most dependable source. Salesmen are familiar with both customer needs and competitive or substitute products. They are therefore in a position to recommend new ideas which have a wide application. Salesmen's enthusiasm, however, may lead them to miscalculate the market for a proposed product or an improved process, and they are also frequently unaware of the technical and financial problems that may be encountered.

Research and development, engineering, and other departments are also an important source of ideas. Technical personnel are familiar with engineering, manufacturing, and use of company products, and, therefore, their suggestions will take into account technical difficulties which will be encountered in the design and development stages. However, technicians and scientists are often unaware of market conditions, and their suggestions must be carefully reviewed from this viewpoint.

Still other companies find that good ideas originate

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[1] Asbury, loc. cit., p. 186.

from outside the organization, by customers, and the general public. The principal idea sources reported by companies in a survey conducted by the National Industrial Conference Board appear in Table 3.

At this stage in the development of an original idea, there should be a screening process to eliminate undesirable projects. Often an organization designates a research project committee on which sales and market researchers are included. In this screening process each project should be classified by type of target. Targets for research projects would be:

1. To find new or better raw materials.
2. To improve existing products or processes.
3. To develop new products.
4. To develop new uses or new markets for existing products or for waste materials.
5. To improve manufacturing methods, equipment, or facilities.
6. To improve handling, distribution, or marketing operations.
7. To improve research methods.
8. To search for basic knowledge on which future research can be built.[1]
9. To reduce costs.
10. To improve quality.

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[1] *Ibid.*, p. 189.

TABLE 3.--Sources of Project Ideas[a]

Originator		Source
1. Sales Force	a.	Knowledge of customer needs
	b.	Inquiries from customers
	c.	Familiarity with competitive products
2. Research and Engineering	a.	Proving ground experiments, performance records, observation of product in use
	b.	Application of basic research findings
	c.	By-product of work on other ideas
	d.	Original thinking
3. Other Departments	a.	Suggestion system
	b.	Analysis of production processes and costs
	c.	Analysis of maintenance costs and operating costs for existing products
	d.	Analysis of markets for existing products
4. Outside Sources	a.	Inventors
	b.	Stockholders
	c.	Management engineers, consultants, etc.
	d.	Purchase of an operating company
	e.	Import of a product exploited successfully in foreign country
	f.	Trade associations and government

[a]Source: National Industrial Conference Board, New Product Development, Studies in Business Policy, No. 40 (New York: National Industrial Conference Board, Inc., 1950), p. 6.

11. To reduce consumer's operating costs.

12. To increase sales appeal.[1]

Evaluating Ideas and Projects

The five primary considerations involved in a research project are: (1) novelty of the idea, (2) utility, (3) usability, (4) research capacity, and (5) costs.[2]

Novelty of the Idea

In determining the novelty of the project, a thorough search of available literature on the proposed product or process should be conducted. This may present some problems in that an immense amount of government-sponsored research is classified.

A second phase of the novelty search is the use of patent literature. A patentability search will uncover such information as clues to unpublished research pertaining to the project, how the project can be guided around existing patented products, information about other organizations active in the field, and reasons why the proposed project may be unsuccessful based on unpublished results. Furthermore, the patent search may show that the project may provide an item which could not be patented.

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[1] Merritt A. Williamson, "High Hopes and Hard Facts in Research Expectations," Research/Development, XIII (April, 1962), 61.

[2] Asbury, loc. cit., pp. 190-198.

Utility

The utility of a project is another factor which must be considered in its evaluation. In evaluating a project it must do one or more of the following things:

1. Reduce the costs of production.
2. Reduce operating costs of the user.
3. Increase the utility of the product.
4. Increase the product sales appeal.
5. Produce new business.
6. Determine technical information that will contribute some other projects.

Usability

In the pre-project stage one of the most important factors is whether the project will fit into the company's interest. No matter how good the idea is, it is not worth spending money on if the results are not going to be utilized. In general, the further the aim of the project are from the aims of the company, the higher the level of corporate decision is needed to justify the project.

Research Capacity

Another important factor which must be considered in establishing a research project is whether or not the skills of the research staff and the equipment of the organization are adequate to support the proposed project. Some of the questions which must be answered in relation to capacity

of the organization are: What are the staff and talent requirements? Are the facilities and equipment adequate, and if not, what capital investments will be required? How quickly should the projects be started? Is it a crash program? What is the deadline for completion? Should several projects be started at the same time?

Having a sufficient number of personnel to work on a project is not enough. If research personnel are not sold on a project idea, the project may be killed. In an ideal, well-balanced organization, there will be sufficient ideas and projects so that unwanted assignments will seldom occur.

Costs

The last but one of the most important pre-appraisal factors is that of the cost of the project. For adequate appraisal of the project, not only the cost of research should be included, but also the costs of production and initial marketing. The subject of evaluation of costs of a research project will be covered more thoroughly in a subsequent section.

Final Selection of the Project

The last step is to assure that research projects which are selected are consistent with established company goals. The process of selection is exceedingly complex, requires much intuitive judgment, and is a process which will frequently have no clear-cut solution. David B. Hertz

has this to say of project selection:

> In the final analysis, it is the top or controlling management of an enterprise which must assume the ultimate responsibility for this choice. Certain criteria upon which to base a critical and rational analysis of the proposals under consideration may be formulated. Their use will aid management. . . . The final decisions must be reached by means of the judgment of those who determine policy for the enterprise, since completely determinative metrical formulations . . . will not be available.[1]

One of the most critical considerations is the size of the company and its financial status. Two factors which are of importance in this connection are: (1) the amount of working capital which can be devoted to research, and (2) the amount of investment capital which can be made available to utilize the results of the research efforts. In the first instance there should be an upper limit established which can safely be expended for research in a given period. In the second instance, companies have been known to invent so many things to manufacture and sell that they are far beyond the capability of an organization with limited capital.

Another factor to be considered before passing judgment on a research project is the competitive position of the concern. In this area, consideration must be given to actual or potential, direct or indirect, geographical and price, and general economic competitive threats. To evaluate proposed projects, top management must have detailed information with

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[1]David B. Hertz, The Theory and Practice of Industrial Research (New York: McGraw-Hill Book Co. Inc., 1950), p. 125.

respect to these factors.[1]

Three preliminary assessments of the possibility of success of a project are offered by W. C. Asbury. These assessments offer no clear-cut solution, but will, however, assist the executive in making a judgment on a project.

> 1. If the project results in the development of a new product not in production, the product would add to the company's line, make it possible to expand business, and perhaps enter into new fields of activity. However, at this point the cost of making this product will not be accurately known.
>
> 2. If the project results in improving an existing product, a rough assessment can be made of the loss to the company if the existing product fails to meet competition. Here the evaluation must be based on the over-all potential loss to the company.
>
> 3. If the project involves an improvement in the process used in making an existing product, the economics of the change may be more susceptible to calculation based on assumptions as to the type of plant that would result from research and development work on the project. Here it is possible to make a rough calculation on the probable rate of return on the new investment.[2]

The above discussion of projects selection has been based primarily on individual judgments of competition, financial condition, marketability, etc. Another approach to the selection process is more systematic and is used by many industrial research organizations. A number of formulas have been developed with a resultant number, or index, which gives the value of a proposed project in relation to others.

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[1] Ibid., pp. 126-133.

[2] Asbury, loc. cit., pp. 198-199.

An example of an equation for determining a project value index for product development is one developed by a chemical company:[1]

$$PVI = \frac{CTS \times CCS \times AV \times P \times \sqrt{L}}{TPC}$$

where:

PVI = project value index
CTS = chances for technical success, on an arbitrary rating scale, say 0 to 10
CCS = chances for commercial success, on arbitrary rating scale, say 0 to 10
AV = annual volume (total sales in units)
P = profit, in dollars per unit
L = life of product in years
TCP = total project cost

Another simple index has been developed by the Industrial Research Institute which provides the net probable monetary return per research dollar.

$$I = \frac{PN}{C}$$

where:

I = index of relative worth
P = over-all probability of commercial attainment of the goal
N = estimated net return for an arbitrary five-year period
C = estimated future research cost

Although the above information concerning project

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[1] Cf., Walter T. Blake, "Project Selection," University of Wisconsin Engineering Institute's Industrial Research Organization, December 13-14, 1956, cited by Asbury, p. 201.

selection is unquestionably helpful to management, the final selection of a project must be based on whether or not it fits research into company goals. In selecting a project for a well planned research program, management should consider the following three broad areas of technology: planning research for (1) present products, (2) for foreseeable new products, and (3) for entirely new applications.[1]

The process commences with the assessment of present products, and the technology required to support these products up to five or ten years in the future. Management should consider markets, competitive technology, and the changing needs of the customers. Planners then compare present research with what is needed to fill the gaps. Projects are selected which will most nearly meet company goals and fill the gaps in the shortest time.

Present products are unlikely to fulfill all company goals, and therefore, the next step should be to consider the projects which offer new products. Here it is important to have (1) good data on market needs, and (2) an analysis of past experience on similar products to give an idea of project success probabilities and project cost.

In the area of fundamental or basic research intuitive judgment basically determines whether a concern has sufficient

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[1] Quinn, "Top Management Guides for Research Planning," Technological Planning on the Corporate Level, p. 192.

basic research to meet company goals. There have been no mathematical formulas and equations which have been found reliable enough to plan specific fundamental programs. However, in considering fundamental research projects, attention should be given to the following:

1. The rapidity with which technical advances are occurring.

2. The competence and enthusiasm of company personnel in the particular field.

3. The availability of qualified persons to staff scientific areas new to the company.

4. The anticipated amount of information yet to be discovered in an area.

5. The relative pertinence of the area's knowledge to company goals.[1]

Another consideration is the life cycle of a product. A schematic portrayal of the life cycle of a new product is shown in Figure 7. The time scale shown in the figure will vary with different products and companies, but the figure does show a traditional cycle which a product usually follows. A typical product creates a loss during the introductory stage, then follows a period of growth and increased sales, and profit. The peak in profits is just before the effect of competition begins to tell. This is followed by a peak in sales, and finally a market decline with reduced profits. The requirement then is to plan ahead for new products to

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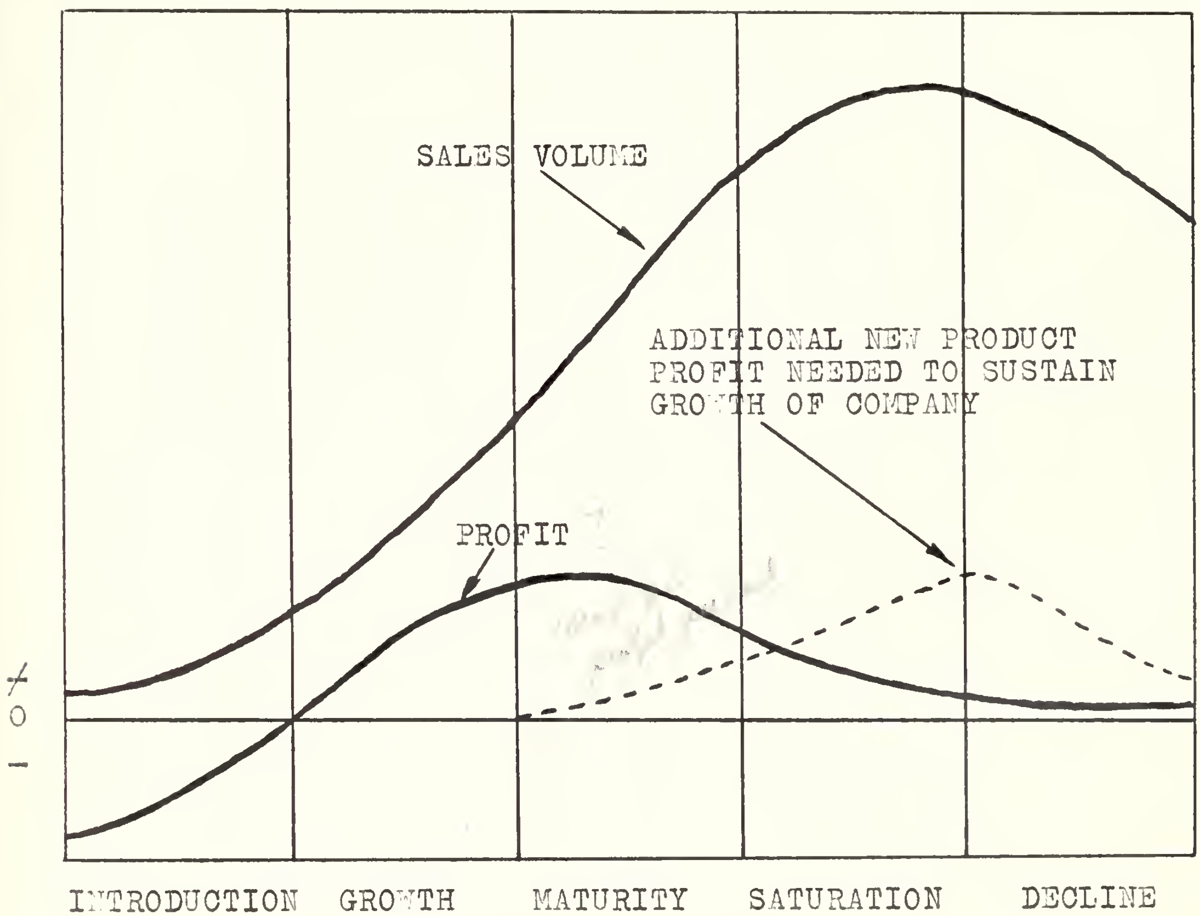
[1] Ibid., p. 195.

Figure 7.--Basic Life Cycle of New Products.[a]



[a]Source: Carl Heyel (ed.), Handbook of Industrial Research Management (New York: Reinhold Publishing Corp., 1959), Figure 7, p. 17.

provide future profits to compensate for the fall-off.[1]

Another illustration showing the relationship of various types of research to company goals is given in Figure 8.

The final stage of project selection is balancing the project selections to meet corporate goals. Management must step back and take a look at their program and see that emphasis is balanced among:

1. Categories of effort. Long- and short-range goals should be supported by adequate basic, applied, and development type research. More fundamental research should be focused on filling future gaps in technology, and applied and development projects should be geared to pay off in the near future.

2. Offensive versus defensive research. Here attention must be given to growth goals versus maintenance of present business.

3. Product lines supported. All present product lines should be supported by programs and projects.

4. Scientific areas. Ensure that all scientific fields which present threats or opportunities within the functional activity of the company are protected.[2]

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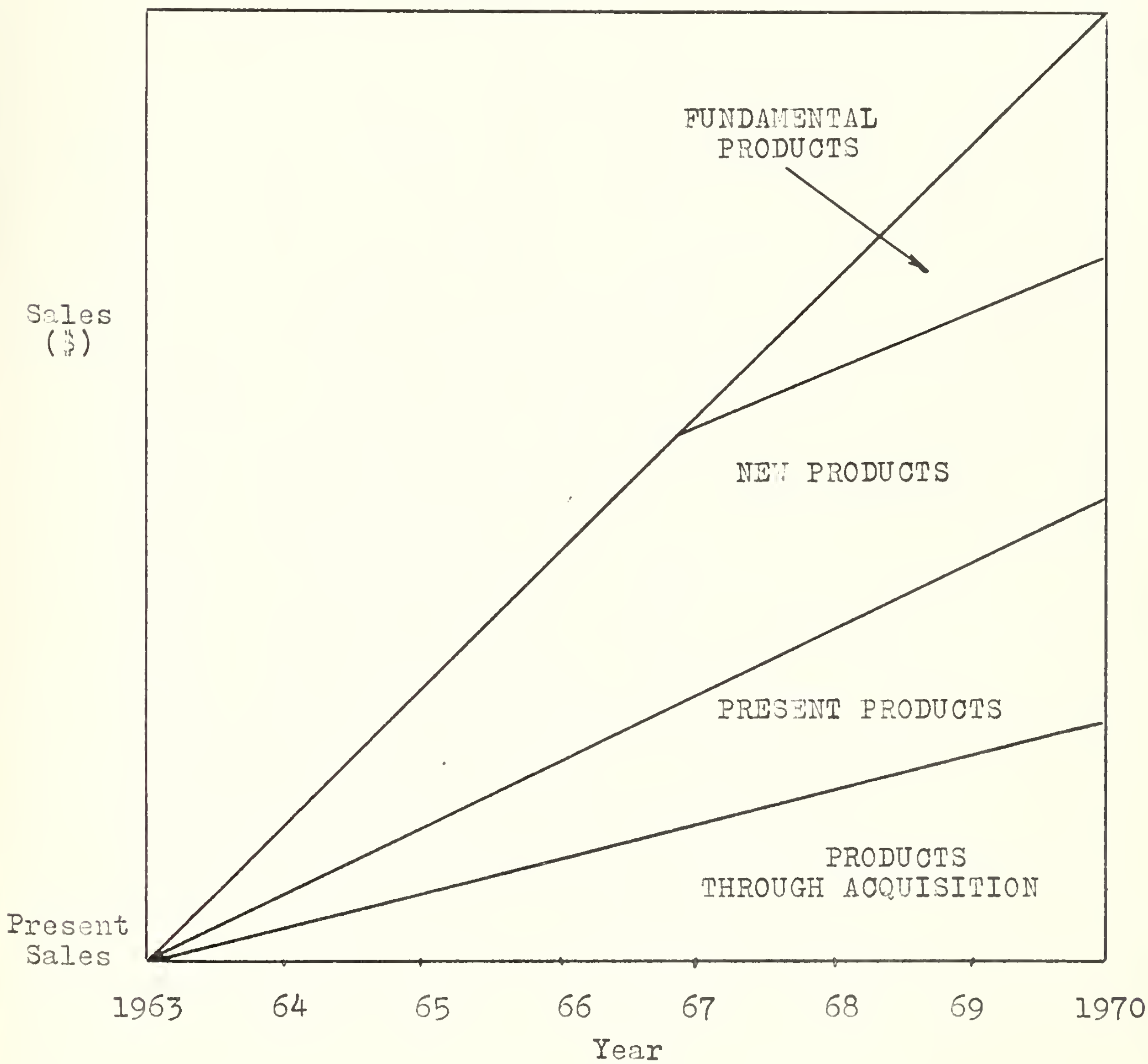
[1] Cf., Heyel, Handbook of Industrial Research Management, pp. 17-18.

[2] Cf., Quinn, "Top Management Guides for Research Planning," Technological Planning on the Corporate Level, pp. 197-198.

Figure 8.--Planning Research to Fulfill Corporate Goals.[a]



[a]Source: James Brian Quinn, "Top Management Guides for Research Planning," Technological Planning on the Corporate Level, ed. James R. Bright (Boston: Harvard University, Graduate School of Business Administration, 1962), p. 194.

CHAPTER IV

EVALUATION OF RESEARCH

Introduction

With the amount of money spent each year for research and development, managers are thinking more and more about the results obtained from research expenditures. Most top executives feel that a reasonable amount spent for research and development will return an adequate profit on their investment. But with growing competition and increased expenditures in the R and D area, management is becoming more and more concerned about measuring and evaluating the results of research programs.

In a report of three group conferences held by the Industrial Research Institute on "Evaluation of Research" in 1961, the following statement appears:

> There is an extremely widespread interest in the development of suitable methods for the evaluation of research. Top management would like to have a fair measure of accomplishments. Research management has been concerned with evaluating the effectiveness of its research program as long as research has been managed. Evaluation of research has been the subject of Industrial Research Institute programs periodically since its foundation in 1938.
>
> Top management has recently intensified its interest. According to National Science Foundation data, research and development expenditures in the United States rose from 5.15 billion dollars in 1953 to 12.43 billions in 1959. Various estimates

> place the expected expenditure in 1970 between 20 and 25 billion dollars. This rapidly increasing outlay of money has been brought into sharper focus by the recent intensification of the profit squeeze. Top management in this atmosphere is asking: (1) whether research investments are worthwhile at all, (2) how research returns compare with those of alternate investment opportunities available to the company, and (3) whether the scientific effort is proceeding with maximum effectiveness.[1]

As used in this section, research "evaluation is the process of judging past performance for the purpose of guiding future action."[2] Management is interested in judging research output in such a way that it will assist in guiding future research and development activities.

> In order to judge past performance in a manner which facilitates the desired kind of administrative action, results of past performance must first be observed; the observed results must then be compared with some established criteria, standards, or bench marks for accomplishment; and, finally, judgments must be made concerning the observed results and comparisons. These observations, comparisons, and judgments should provide a logical basis for taking corrective action concerning the current program and for planning future action to exploit observed research results or to initiate a new phase of the research program.[3]

The purpose of research evaluation is better to utilize the human and economic resources which a company devotes to the research program. Many contributions should

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[1] James W. Hackett, "Proceedings of Industrial Research Institute Study Group Meeting. Number 7. Evaluation of Research," Research Management, V (May, 1962), 177-178.

[2] Quinn, Yardsticks for Industrial Research, p. 8.

[3] Ibid., pp. 8-9.

be made to industrial research management by an adequate evaluation system. For example:

1. Weaknesses in plans or in action taken may be observed and corrective action can be taken where necessary. There is little consequence in establishing goals, guidelines, and objectives if the results are not measurable.

2. Management may avoid repeating errors and utilize past performance in planning future programs and projects.

3. The results of each research project may be appraised for maximum commercial exploitation.

4. The output of technical personnel may be better measured and the motivation of research personnel may be improved. If the achievements of research are recognized, management can provide a stimulus for the entire research organization.

5. The financial control of research will be simplified and a better indication of capital requirements for the support of the research program and exploitation of results.

6. Coordination of all functional activities may be improved. Continued evaluation of research results assist in the integration of research programs into the needs and capacities of the company.

7. Comparisons with competition are simplified, and the company can judge how it is maintaining its technical

position in the industry.[1]

It is quite obvious that evaluation is important. Some of the aspects of this phase of research management have been discussed quite thoroughly by current writers and various organizations. Some propositions concerning the evaluation of research and development are listed below:

1. Any executive or manager of today recognizes that research is an integral partner in the existence and growth of a company. Due to the highly competitive conditions of today, management is looking for more sophisticated techniques for the evaluation of research.

2. Evaluations of past results, especially when compared with past pre-evaluations, are of benefit in improving pre-evaluation techniques; it provides management with a measure of the efficiency of the R and D organization, and, in addition, provides the R and D personnel with an indication of their effectiveness and contributions to the organization.

3. There are very definite benefits from attempts to broadly evaluate research and development. Those companies using evaluation techniques are convinced that they are improving the research process.

4. Better records and better feedback of costs and profits are required for better evaluation. Added effort and

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[1]Cf., Quinn, "Measurement of Research Accomplishment," Proceedings of the Eleventh National Conference on the Administration of Research (University Park: Pennsylvania State University Press, 1958), pp. 67-68.

expense are usually required for proper evaluation.

5. Attention is focused on new product output and profitable marketing of the product. All research is not successful, and cost cannot be pre-evaluated with a high degree of accuracy. The time lag in research and development must be taken into consideration. In judging the value of a proposed investment, the time value of money must be considered.

6. No accurate and universally applicable evaluation techniques are available; however, research may be evaluated in an abstract or subjective manner by comparing contributions and accomplishments with pre-established objectives and criteria of success. Certain phases of research are measurable in dollars to a certain degree of accuracy.

7. A criteria for success must be established before proper evaluation can be conducted. Whenever possible a dollar criteria should be established. However, a crosscheck involving non-profit dollar objectives should be used whenever possible. This is because final dollar profits are not dependent upon research alone.

8. Intuitive judgment is a dominant factor in all evaluation methods.

9. Top management must understand the methods used to evaluate research and development. They, after all, are the ones which are primarily concerned with the contributions made by R and D.

10. The absolute dollar result cannot be attributed

solely to research. Other members of the business team such as sales, marketing, planning, and finance contribute to the success of a product in most cases.

11. Research evaluation should be on a long, not a short-term basis.[1]

Although the benefits which can be derived from thorough research evaluation is impressive, no generally applicable solution to the problems of research appraisal for management purposes has yet been developed. In a national survey conducted by the National Science Foundation in 1956, only forty-six companies out of approximately two hundred interviewed reported having formal methods for estimating research returns.[2]

Approximately one-third of the companies represented at a 1961 conference of the Industrial Research Institute on "Evaluating Research" have adopted formal evaluative procedures to some degree. The approaches vary from attempts to develop methods for evaluating the total R and D effort, to limiting the effort to but one product or process. The aim is usually a ratio representing the output in terms of dollar

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[1] Cf., James W. Hackett, "Evaluating the Results of Research," Technological Planning on the Corporate Level, pp. 232-234.

[2] National Science Foundation, Science and Engineering in American Industry (Washington: U. S. Government Printing Office, 1956), p. 49.

profit to the dollars input to R and D.[1]

Even among the formal systems, most concerns rely on individual judgments more heavily than precise formulas and equations. Few claim to have evolved formulas for evaluation, and others say that they have not even tried to find an evaluation formula.

Most companies admit that research evaluation poses problems which are unique and still have not been solved. Some of these problems are discussed below.

Problems of Evaluation

There are many differences between the evaluation of research and the evaluation of more repetitive operations such as production. For the latter, evaluation is simply a matter of comparing performance against standards which have been accurately producted well in advance. Unfortunately, research evaluation is something quite different. One of the major problems is that intended results are frequently not accurate enough to serve as standards for performance.

A major problem in forecasting research performance is lack of repetition in research operations. Even with the most accurate past data, the time and cost of future problems is often difficult, if not impossible. Research schedules

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[1] James W. Hackett, "Evaluation of Research," *Research Management*, V (May, 1962), 185.

are primarily estimates based on broad experience with similar problems.

Another obstacle in establishing standards is that not even the best director of research or top executive can predict what a particular research project will eventually yield. Except in the most applied phases of research, the outcome of an experiment is usually quite unpredictable. Some projects which have been underway for years may yield dramatic results in a matter of a few hours, or, conversely, the most promising project may suddenly encounter insoluble problems.

Judging the worth of observed results is complicated by at least three major factors:

1. Research results are often intangible ideas which require the participation of other functional activities before they become materially or economically useful. Therefore, one must be careful to give research only the credit which is due. Research should not be given full credit for an obvious team effort.

2. Even after a project has been successfully completed, it may be years before the full economic impact is felt. For example, DuPont has introduced within the last decade several products based on basic research which started in 1927. It is impossible today to estimate the market potential of some of these products.

3. The products of research are mixed and varied, and there seems to be no way in which the relative value of one type of output can be compared with another. The lack of comparability of results has led directors of research to search for a formula which will link all outputs in terms of a common denominator. None of these formulas have proved completely satisfactory, but some are being used.[1]

Current Evaluation Techniques

Over the years management has devised a number of methods of evaluating research results. Three dominant themes are found in current thinking: the quantitative approach, the qualitative approach, and the integrated approach to research evaluation. All have proved to offer some advantage and to contain limitations. In the following pages the three main currents of thought will be explained.

Quantitative approach

The quantitative approach to research evaluation makes use of mathematical formulas to measure the profit contribution from a research and development program. Many companies rely on this formula technique exclusively, and others use it to some extent. Normally, the formula relates one or more of the following factors and purports to estimate the total contribution of the R and D program:

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[1]Quinn, Yardsticks for Industrial Research, pp. 10-14.

1. Profits from research-created new products.

2. Profits from cost-reducing new or improved processes, methods, or raw materials based upon research technology.

3. Profits from improved products.

4. Savings from royalty payments avoided.

5. Income from royalty payments received.

6. Miscellaneous profit contributions resulting from general good will created by the research establishment.

7. The investment in the R and D program or the total investment to bring research technology to commercial fruition.[1]

Quantitative discussions dominate the literature on research evaluation with new formulas quite often appearing. Perhaps the best known of these is the "Index of Return" method originally advanced by Dr. Fred Olsen, of Olin Industries, Incorporated. This method assigns varying measures of return to be compared with the estimated cost of research as follows: on process improvement projects, process savings for one year; on improved products, two percent of the sales value for two years; on new products, three percent of the savings for five years. The over-all index of the program is the sum of the values of the individual projects as defined below:

I. R. = (Value of process savings for one year plus three percent of the sales value of new products each year for five years, plus two percent of the sales value of improved products each year for two years.)

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[1] *Ibid.*, p. 18.

For estimating the potential return of proposed projects, similar formulation is used, modified by an estimated "probability of success."

$$\text{Value of new products} = \frac{(\text{estimated I. R.}) \times (\text{probability of success})}{\text{estimated cost of research}}$$

A ratio lower than three to one in the above formula is usually considered too low to consider a project worth while.[1]

A lumber company classifies its research results into three groups and rewards them accordingly:

> (1) Projects which have been concluded successfully and put into operation. It is assumed that the value of these discoveries is four times the cost of the research. (2) Projects which have been completed successfully and are of definite value to the company in improving operations but on which no well-defined action has been taken. An example of this might be investigation which has kept the company from spending money on a questionable process. Projects of this sort are assumed to be worth twice the cost of the research. (3) If the project is unsuccessful, obviously, no credit is taken.[2]

> A large chemical company selects a committee from research, production, and sales to determine the percentage contribution of research on a new product or an improvement of an old one. Research is given a credit amounting to this percentage times the profit on the item. If a major improvement is made

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[1] Robert M. Bowie, "Top Management Reports and Controls," Handbook of Industrial Research Management, ed. Heyel, pp. 346-347.

[2] Allen Abrams, "Measuring the Return from Research," Proceedings of the Fourth Annual Conference on Administration of Research (Ann Arbor: Engineering Research Institute, University of Michigan, 1951), p. 23.

on a process, the savings are credited to research.[1]

The above examples briefly describe a few of the many accepted and publicized methods for quantified research evaluation. By far the greatest number of industries use the qualitative judgment method of evaluation. Table 4 shows some statistics concerning the degree to which managers rely on quantitative appraisals.

TABLE 4.--Relative reliance on quantitative evaluation devices.[a]

Reliance on Quantitative Measures	% of Companies
1. Rely heavily on quantitative devices	14.8
2. Use some quantitative devices but depend primarily on individual or group judgment	48.2
3. Rely little or not at all on quantitative evaluation devices	37.0

[a]Source of data: Quinn, Yardsticks for Industrial Research, p. 16.

Qualitative approach

Other companies which do not rely on the quantitative approach prefer to base their evaluation on managerial judgments exercised by individual executives or committees. They simply evaluate by general feelings of accomplishment or the adequacy of the over-all program. No attempt is made

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[1]Quinn, Yardsticks for Industrial Research, p. 16.

at a single quantitative measure of the research and development accomplishment.

Most qualitative systems follow a similar pattern. In making subjective management appraisals which are characteristic of the qualitative approach, a series of personal appraisals are made from the worker level on up to the top management level. At each level a technical executive evaluates the technical progress of groups reporting to him. The reports and reviews are fed up the line for ultimate interpretation by top management, ordinarily a non-technical executive. This top man is thus in the unique position of being the ultimate authority for reviewing the efficiency and effectiveness of his own organization.[1]

Those who argue in favor of the qualitative approach have these comments:

1. Individual judgment is as adequate as mathematical formulas. Broad composite managerial judgments are better than mathematical formulas which are based on inaccurate estimators.

2. Judgment is the only method of evaluating some phases of R and D. Such measures as efficiency of research efforts, quality of output, and the appraisal of current results of long-range programs are impossible to evaluate

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[1]Quinn, "Measurement of Research Accomplishment," Proceedings of the Eleventh National Conference on the Administration of Research, pp. 69-70.

mathematically.[1]

3. Formulas cannot be relied on to evaluate research. Mathematical evaluation can be used as a check on judgment to ensure that all factors of importance are considered.[2]

A fairly typical example of the qualitative evaluation process is described in the following manner by a large chemical concern:

> The evaluation of the results of research is a continuing process. Each level of the organization constantly evaluates its activities and those of all groups for which it has responsibility. This process is formalized in some aspects, but quite informal in others. 'Evaluation of the activity is the day-to-day job of the research administrator.' 'In a complex technical situation, it is necessary to try any method which can be conceived to evaluate research.' Thus, a variety of techniques is used at all levels of the organization. No single method receives extensive attention. Evaluation is done on a program-by-program and project-by-project basis. There is a constant evaluation and re-evaluation by the whole team.
>
> There are at least quarterly meetings of sales, production, research, and finance people. They review the past results and present projects of research by 'intelligent judgment.' These meetings 'provide a background by which operating and Research people are oriented to the company.' The criteria used at these meetings are 'integrated management judgment.' Economic evaluations are said to be made continually from the time the idea is first conceived until final exploitation. The economic estimates are necessarily broad at first, but can be more accurate as the results become more concrete.
>
> This concern has made periodic mathematical studies of the value of specific programs by matching

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[1] Ibid.

[2] Quinn, Yardsticks for Industrial Research, p. 23.

> the total program cost against the total profit hield of its results. No generalizations could be made from these studies except that the contribution of research computed on this basis is so far above the marginal level as to make computations in detail unnecessary.[1]

Compromise approach

A third method of evaluation, which combines both methods, has been advocated by Professor Quinn in what he calls an integrated or segmental approach to research evaluation.[2] It is not focused on the total research contribution, but, instead, evaluates the major segments of the research program. These segmented evaluations are a composite of many of the techniques of evaluation presently in use. In this method the total process of evaluation is initially divided into technical evaluation and economic evaluation. The procedures of this system are summarized as follows:

Technical evaluation.--This procedure appraises (1) the efficiency of planned technical results, and (2) the quality of research work produced. Efficiency evaluations include qualitative appraisals of the time and cost consumed in accomplishing a planned objective. Comparisons of actual times and costs are compared with subjective standards. There

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[1] *Ibid.*, p. 26.

[2] The description of this segmental evaluation system proposed by Professor James Brian Quinn is explained in *Yardsticks of Industrial Research*, Chapter 9, and "Measurement of Research Accomplishment," *Proceedings of the Eleventh National Conference on the Administration of Research*, pp. 70-77.

are no formal standards in writing, but the evaluator judges on the basis of experience in similar work.

The quality evaluation is a qualitative appraisal of the skill, creativity, and technical proficiency shown by the researchers. Again this is a subjective evaluation. No quantitative measurements in this area have been devised, and the only standard of measurement used is the experience of the evaluator.

Economic evaluation.--In the long run a company's research expenditure must be justified in terms of dollar profits. Assessing the profit contribution constitutes economic evaluation. The profit contribution of offensive research, which allows a company to exploit new markets, is relatively easy to assess. Once a new market is established, evaluators can evaluate the profit or loss by standard accounting procedures.

Defensive research, which is directed toward improving the competitive position in existing markets, is primarily accomplished by (1) cost-reducing processes, (2) raw material developments, (3) waste salvage developments, and (4) improvements in the quality of existing lines. Process developments and other developments which reduce the cost of production can readily be appraised by standard quantitative methods. Product improvement research is difficult to evaluate, as there are no valid techniques for establishing in financial terms

the cost of not having performed product improvement research. The most useful device of measurement is a product comparison where the product is compared with <u>all</u> competing products. Such comparisons show up strengths, weaknesses, and the over-all product quality.

In the over-all appraisal of the research and development contribution, Professor Quinn has this to say:

> Evaluators should develop . . . tools for measuring and evaluating the output of each important segment of the research program rather than devices for assessing aggregate research contributions. Quantitative devices should be used in making segmental evaluations where they are helpful in making decisions concerning the particular aspect of the program being evaluated, but mathematical techniques should be avoided where they do not measure what they purport to assess. In the evaluation of some aspects of research output quantitative techniques are extremely helpful. In many others managers must rely on well-founded subjective judgments.
>
> Different criteria and different techniques are required to appraise each important segment of an industrial research program. One can no more sum all of these techniques and criteria into a single measure of research effectiveness than he can sum oranges and locomotives and have anything but the same oranges and locomotives. Appraisals of research accomplishment should carefully assess each major segment of research output. Only the broad composite judgments of qualified individuals can sum and integrate these appraisals into an assessment of over-all research effectiveness.[1]

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[1]Quinn, <u>Yardsticks for Industrial Research</u>, p. 202.

CHAPTER V

CONTROLLING RESEARCH

Introduction

Research and development activities are becoming major functions in many companies. This has been emphasized by the large sums of money spent annually for research and development, the sizeable research organizations in many companies, and the high proportion of income which is attributable to products that have emerged from past research.

In addition to managerial planning with which to guide research efforts toward company goals and objectives, there is a definite need for control to prevent deviation from established objectives. Dr. Merritt A. Williamson, Dean, College of Engineering and Architecutre, the Pennsylvania State University makes the following statement concerning the control of research activities:

> I realize full well that in R and D activities the word "control" is considered a nasty word. But the fact remains that control is everywhere. Most R and D directors I know try hard to maintain control over their operations, but they usually keep quiet about it and they do not discuss in detail the procedures they use. In fact, I doubt that many of them think of their operations as effecting control. The problem in R and D management is how to strike the critical balance of still controlling yet allowing such freedom

so that creative effort is not stifled in the process.[1]

Planning and control seem to be synonymous with the word management. The planning phases have been discussed in Chapter II, and this paper would hardly be complete without some discussion of control. Management writers during the past decade or more have emphasized the need for planning, directing, controlling, evaluating, and appraising. An examination of various writings show there are many definitions of the word "control." The various definitions, the techniques of control presently employed, and the purposes of control are too numerous and varied, and, therefore, are beyond the scope of this paper. However, most writers do agree that control must exist in practice for profitable, effective, and efficient operations. It is also agreed that control is obtained by means of one or more of the following managerial tools: policies, organization, procedures, standards, records, reports, and budgets.

One of the most effective means of exercising control of research and development activities is by controlling the application and amount of funds available. The following section will deal with some of the financial control aspects, specifically the R and D budget and cost control techniques.

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[1] Merritt A. Williamson, "Instituting Effective R and D Management Controls," Research/Development, XIII (November, 1962), 39-40.

The Organization of the Research Function

The purpose of research has been defined in terms of the responsibility of management "to provide the technical leadership necessary in order for the company to earn a satisfactory return on its invested capital, both this year and especially down through the years to come."[1]

This responsibility can be restated in the form of three objectives:

1. To maintain the company's prestige and profits by keeping existing products competitive in quality and price.

2. To improve the company's competitive position and increase profits by developing new products that replace or supplement existing products and by improving present products to a point where they have greater acceptability in the market.

3. To explore possibilities for expansion into related or unrelated fields that offer opportunity for substantial profits.[2]

The relative emphasis placed on the above objectives varies among companies. The diversity of activities and purposes, therefore, tends toward various method of controlling and accounting in industry. Furthermore, it is difficult to assign costs to products and to measure results as described

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[1] Ralph H. Manley, "Translating the Economic Aspects of Company Policy into Research Policy," paper read before Fifth Annual Conference of Industrial Research, Columbia University, 1954 quoted in "Accounting for Research and Development Costs," N.A.C.A. Bulletin, XXXVI (June, 1955), 1377.

[2] Ibid., pp. 1377-1378.

in a previous section.[1] The principal reasons are that the outcome of research is always somewhat uncertain, and usually there is an appreciable time lag between the incurrence of research costs and the realization of benefits.

Due to the importance of research today, most companies have established separate organizational units with specific functional responsibilities. While the size of the company, the scope of the research program, company objectives, and the type of research all affect the functional organization, there is a general pattern in the practices of most companies. Research and development is ordinarily distinguished from regular operating functions which are performed by engineers and other technical personnel. The head of the research department is usually sufficiently high in the organization of the company so that research personnel are able to concentrate on genuine research problems without being diverted to solve problems of a routine technical nature. A typical organizational plan is illustrated in the following example:

> A large manufacturer of mechanical products has three operating divisions organized by products and markets. Three central staff departments (central production staff, central marketing staff, central engineering staff) headed by vice-presidents have been created to serve the operating divisions. General and basic research functions are headed by a director of research who reports to the vice-president in charge of the central engineering

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[1] *Supra*, pp. 62-78.

> staff. In addition, each operating division includes a product development department responsible for experimental work aimed at improving existing products and manufacturing processes.[1]

The organization of internal budgeting and accounting functions within the research activity is largely dependent upon the size of the company and its research laboratories. In larger organizations budgeting and accounting functions are separated from the technical functions. However, regardless of whether the executive in charge of research has his own administrative staff or utilizes a central administrative service department, he is responsible for the financial plans of the research and development budget. One company manual of budget procedures states that:

> Annually, budgets covering research expense are prepared under direction of the Research Director's Office, with assistance of the Office and Service Manager of the research center and of the corporate budgeting and accounting department.[2]

The above statement points to the fact that decisions concerning application of research funds are made by line management.

The Research Budget

Dr. Merritt A. Williamson makes the following statement concerning the budget as a management control tool:

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[1] "Accounting for Research and Development Costs," N.A.C.A. Bulletin, XXXVI (June, 1955), 1379.

[2] Ibid., p. 1383.

> In my opinion, the most effective method of control is the distribution and allocation of that important item known as money. If an area receives no support it cannot get out of control! A budget may be defined as a basic business policy stated in accounting terms. It does not come naturally to research men to think of their assignment in budgetary terms, but for those who are removed from the work at hand, the best indication of what is going on may be obtained by a study of actual expenditures and a comparison with budgeted expenditures. Such data are used as means of control and they deserve very careful attention in their preparation and their periodic reporting. If a manager at any level understands the true nature of a budget, it can do wonders for him and his group.[1]

Dr. Williamson and many other management writers agree that the principal financial control tool for research activities is the budget. By means of the budget, management can control the amount of money spent and can sometimes direct the way money is spent. One company surveyed by the National Association of Cost Accountants had this to say concerning control by budget:

> Control is exercised primarily by having top management set an appropriation which is a maximum not to be exceeded because it has been determined by the financial position of the company. This is then broken down and similar maximums are set for projects and jobs under each project. These allowances are not to be exceeded without authorization, but the programs within the annual appropriation are reviewed from time to time. . . .[2]

Budgetary Objectives

In current literature it is constantly stated that,

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[1] Merritt A. Williamson, "Instituting Effective R & D Management Controls," Research/Development, XIII (November, 1962), 42.

[2] N.A.C.A. Bulletin (June, 1955), p. 1394.

to be effective, management must plan, coordinate, and control; practice management by exception; improve communications; delegate authority; etc. A budgetary planning and control program is a system where all aspects of management are brought into a coordinated whole. Some of the results from a well thought-out budget program are summarized by B. F. Coggan, Vice President of Convair:

> 1. Such a program should take the . . . plans of a company and tie them into a unified whole. . . . It requires a definition of objectives and setting up a program to carry out these objectives.
>
> 2. The budget program should bring about a coordination of activities . . . to carry out the over-all plan.
>
> 3. The budget program should be a means of control to carry out the over-all plan. Responsibility should be assigned for each kind of expenditure. Budget reports should measure performance against the approved plan. Deviations from the plan should be quickly detected, analyzed, and remedied.
>
> 4. The budget program should promote more economical use of working capital.
>
> 5. The budget program should reduce waste and promote efficiency.
>
> 6. The budget program should place responsibility for action on those who have been assigned the task.
>
> 7. The budget program should bring about better business judgment by reducing plans to figures.
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> 8. The budget program should flag possible trouble areas.
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> 9. The budget program should provide a means of determining financing needs.[1]

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[1]B. F. Coggan, "What Management Expects from the Budget," Business Budgeting, VI (January, 1958), 13.

Budgeting is a financial plan which establishes a working understanding between individuals. For example, management first gives the subordinate a job to be done; the subordinate plans the job and submits recommendations to management; and the two agree on a budget to guide in the execution of the plan. A proper budget philosophy encourages independent thought and generates ideas. A budget is an operational plan stated in figures, the indispensable preliminary to control and cost reduction.[1]

Prior to World War II it was thought that planning research and development would stifle creativity. However, with the pressures of wartime and the increased industrial outlays for research, better planning techniques were required.

As a result, major research programs were broken down into elements. These various elements were assigned as the responsibilities of individual scientists. All of the various elements were combined into a coordinated plan called a program. Carefully planned schedules were set up leading toward the major programs and objectives. As time went on, management became well aware that this planning for research was much more efficient and effective than previous, less formal methods.

It became obvious that if all phases of the research effort could be planned and scheduled effectively, the funds could also be scheduled equally well. This led to research

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[1]James L. Peirce, "Control by Budget," The Controller, XXV (July, 1957), 328.

budgeting. Since the early stages of World War II research budgeting has been accepted by more than seventy percent of research sponsoring institutions as an aid to planning R and D activities. Most of the remaining thirty percent are quite small and therefore do not require the formal techniques of planning and budgeting.[1]

The research budget is primarily a planning tool which allows management to plan and guide research in the desired direction. In other words, management controls research activities by limiting the research budget. Specifically, budgeting assists research planning in several ways:

1. It insures periodic review of research programs, by control of expenses before, rather than after, they are incurred. Managers are forced to periodically review and replan their programs to conform with the budget. Two very important aspects of this periodic review is that programs cannot be allowed to grow haphazardly for extended periods of time, and the review at periodic intervals stimulates researchers to show progress.

2. It forces the manager to plan programs more concretely. The careful planning and scheduling required by budgeting helps all research personnel to interrelate all aspects of the research program and various activities. In

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[1]James Brian Quinn, "Budgeting for Research," Handbook of Industrial Research Management, p. 281.

that researchers from all levels must plan their activities, they become more mindful of the need of progress toward goals and objectives and the price of this progress.

3. It helps to coordinate research activities with short- and long-range corporate plans, goals, and objectives. The important balance between program segments must be watched. The budget allows adjustment of expenditures between various program segments. A method of showing how much effort is being devoted to various segments of the research program is shown in table 5, which is called a research balance sheet. In addition, the budget encourages the exchange of ideas during the planning stage. In short, the budget is a major device for coordinating the plans for the entire organization.[1]

TABLE 5.--Percentage of total research budget devoted to each segment[a]

	New Product			New Process			Product Improvement			Total
	Product Line			Product Line			Product Line			
	A	B	C	A	B	C	A	B	C	
Fundamental	2	3	-	1	2	2	-	4	1	15
Applied	10	7	3	9	7	5	4	1	4	50
Development	6	2	4	7	1	3	2	2	8	35
Total for Product Line	18	12	7	17	10	10	6	7	13	
Total (%)		37			37			26		100

[a]Source: James Brian Quinn, "Budgeting for Research," Handbook of Industrial Research Management, ed. Carl Heyel, Fig. 1, p. 284.

[1]Ibid., pp. 281-285.

How much to spend

In developing the research budget many companies use a fixed percentage of projected sales. The advantages of this method are: (1) simplicity, (2) general availability of projected sales data, and (3) the ability to keep research expenditures within available funds. The major disadvantage of this system is that whenever sales forecasts show a downward trend, researchers are forced into curtailing programs. Cutting back on programs has an adverse effect on long-range projects and injures the continuity and organizational stability needed for effective research. Generally a decline in sales indicates a need for more, not less, research. The majority of research managers feel that sales projections should be used as a yardstick, but should not be adhered to rigidly.

The relation of research and development to net sales is probably the most widely used measure of the importance of R and D activities within a company or within an industry. This relationship provides a common denominator by which management of a company can compare R and D activities with that of the industry. Individual companies try to match or exceed the average ratio for the industry. The results of a recent study conducted by the National Science Foundation are shown in Table 6.

Another method of establishing research budgets is

TABLE 6.--Funds for research and development performance as percentage of net sales, in manufacturing companies performing research and development by industry and size of company, 1959.[a]

Industry	Total	Companies with total employment of --		
		Less than 1000	1000 to 4999	5000 or more
Total	4.2	2.2	2.1	4.9
Food and kindred products	.3	(b)	.2	.3
Textiles and apparel	.5	.5	.5	.5
Chemicals and applied products	4.3	2.0	3.1	5.2
Rubber products	2.0	1.1	.9	2.2
Machinery	4.2	2.9	1.9	5.8
Fabricated metal products	1.7	1.0	1.0	2.7
Electrical equipment and communications	11.3	6.1	5.0	13.6
Motor vehicles and other transportation equipment	3.4	(b)	1.0	3.6
Professional instruments	8.3	5.1	5.3	10.7

[a]Source: National Science Foundation, Funds for Research and Development in Industry, 1959, Surveys of Science Resources Series, NSF 62-3, Table A-20 (Washington: U. S. Government Printing Office, 1962), p. 72.

[b]Not separately available but included in the total.

the use of competitor expenditures as a guideline. Sources of funds used by competitors include published financial statements, estimates of research space used by competitors, number of personnel employed, expansion of activities, and so on. This system has the advantage of keeping the company constantly attuned to the activities of its competitors. However, this system is basically defensive. It does not indicate how much more profit could have been made had research expenditures been increased. Another factor to be considered is the objective of the competitor companies. Unless the objectives of both companies are the same, research expenditures are meaningless figures. As with the case of the projected sales figure, the competitor's budget should only be used as a guide, and not as a final standard or basis for the research and development budget.

Still other companies base research budgets on company growth rate in line with basic corporate objectives. If for example a company plans or projects growth at the rate of 10 percent annually, then research and development budgets are also increased at that rate, regardless of competitor forecasts or projected sales figures. This system has the definite advantage of integration of the research budget with long-range corporate planning. Of course, for a workable system, the long-range program and the project selections must be realistic.

Another method of budgeting is to develop projects

based on their own merit. Each potential project is evaluated on the basis of potential profit to the company. The rate of return of each project is then compared against some predetermined standard. The higher the project's yield in comparison with the standard, the more desirable it is. The company supports and budgets projects which seem best to fit corporate objectives. The disadvantage of this type of approach is that it is difficult to measure accurately the ultimate financial potential of a project.

The use of formulas in selecting and evaluating research projects has been discussed to some length in previous sections. Formulas are also used to indicate some of the important factors in considering total budget levels. Projects can be ranked on the basis of effective rates of return and then compared with cost or risk standards. One such formula for determining project acceptability is known as the Calculated Risk Formula:[1]

$$R = \frac{\sum_{i=0}^{n} \left[P(I_i)\right]}{\sum_{i=0}^{n} \left[(O_i)\right]}$$

Where:

I_i = net estimated income from the project's results in any i^{th} year

n = the last year in which incomes are expected

[1]Ibid., p. 298. A number of other formulae that have been quite useful in industrial research are discussed in Quinn, James Brian, Yardsticks for Industrial Research (New York: The Ronald Press Co., 1959).

P = probability of receiving the i^{th} income

O_i = the net incremental investment in any i^{th} year

i = the year hence in which the income or outlay will occur

R = the project's rate of return on total funds invested

Another technique for establishing the amount to be budgeted for different purposes was described by Ralph H. Manley in a paper presented at an Industrial Research Conference. In approaching the question of how much to appropriate for research, two purposes should be recognized which are:

> 1. To maintain the company's current position in the face of . . . competition. This is called product maintenance and consists of improving existing products and processes. . . . The amount we must spend on such work in relation to sales or profits depends upon the nature of the business and specially upon the caliber of our competition. In the packaged food field in which competition is tremendous, today's market leader soon becomes tomorrow's "Model T" unless a new and improved model is constantly in course of development.
>
> 2. To insure continuation and growth into the future. Two types of research contribute to this purpose, viz., (1) fundamental research in the company's field of interest, and (2) development of new products. Since the amount of product maintenance research is largely determined by what must be done to keep abreast of competition, fundamental research and new product development constitute the principal areas where decisions must be made relative to how much and what kind of research to carry on.[1]

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[1]Ralph H. Manley, "Translating Economic Aspects of Company Policy into Research Policy," paper presented at the Fifth Annual Conference on Industrial Research, Columbia University, 1954, quoted in N.A.C.A. Bulletin (June, 1955), p. 1397.

It is obvious from the above paragraphs that there is no best method or technique in establishing the amount to be spent on research and development projects. Some companies use a rule-of-thumb method, others use a sales projection figure, others may use a sophisticated formula, and others may use intuitive judgment. Whether one of the above or a combination of various methods are used, the amount determined for the research budget is the first step in management financial control of the research activities.

Preparing the detailed budget

The process of preparing the research budget differs considerably from that followed in preparing a manufacturing budget. In preparation of the latter, management begins with the expected volume of production or sales, whereas the detailed budgeting of research costs starts with the consideration of personnel and facilities available. The number of qualified scientific and technical personnel is the key to the research budget.

Generally the detailed research budget is divided into two separate documents, one by source of expense and another by projects.

Source of expense budget.--The first of the two types of budget presentations is comparatively easy to prepare. The degree of complexity is largely dependent upon the amount

of money involved, the size of the research organization, and the amount of detailed information required. The basic classifications would include: payrolls, supplies and materials, and other direct operating costs. A description of some of the typical classifications of the expense budget are outlined below:

1. The payroll section might include:
    a. Salaries of professionally trained scientists
    b. Salaries and wages of laboratory technicians, draftsmen, etc.
    c. Wages of service employees, etc.
    d. Wages of hourly workers borrowed from operating departments as required.
2. Materials and supplies consist of two major categories:
    a. Expendable equipment purchased for specific projects
    b. Supplies and materials of a more permanent nature
3. Other direct costs:
    a. Books, periodicals, professional dues, etc.
    b. Travel expenses
    c. Taxes, depreciation, and insurance
    d. Costs of service facilities[1]

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[1] Adolph G. Lurie, "Controlling Research Costs with a Budget," Administrative Control and Executive Action, eds.

<u>The project budget</u>.--Although it once was common to budget only the total R and D cost, now only the smallest of organizations budget without the project budget. Most companies feel that the important phase of research budgeting for cost control is the project budget formulation. Major classifications of the project budget might include:

1. Improvement in the manufacture of present products
2. Research and development of new products
3. Projects requested by customers or other departments
4. Fundamental or basic research having no commercial value
5. Balance vailable for projects to be authorized at some future date.[1]

Figure 9 is a sample project budget similar to the type described above. The total of the various items in this budget should agree with the amount indicated on the source of expense document. The total budget amount for each project is an important factor for management control purposes. Control of the total expenditure should be maintained to decide whether a project should be continued or scrapped. A more detailed type of project budget is shown in Figure 10.

B. C. Lemke and James Don Edwards (Columbus, Ohio: Charles E. Merrill Books, Inc., 1961), pp. 279-280.

[1] <u>Ibid</u>., p. 284.

Figure 9.--Research and Development Project Type Budget.[a]

RESEARCH AND DEVELOPMENT DIVISION

Project Budget
Year Ended December 31, 1962

	Current Budget	Prior Expenditures	Total Authorized
1. Present products			
a. Projects in progress			
(1) Product x improvements	$ xxxx	$ xxxx	$ xxxx
(2) Product y usage	xxxx	xxxx	xxxx
(3) Product z quality	xxxx	xxxx	xxxx
b. New Projects			
(1) Product x new process	xxxx	xxxx	xxxx
(2) Product y quality control	xxxx	xxxx	xxxx
(3) Product z new use	xxxx	xxxx	xxxx
Total present products	XXXX	XXXX	XXXX
2. New Product Research			
a. Projects in progress			
(1) Product xx	xxxx	xxxx	xxxx
(2) Product yy	xxxx	xxxx	xxxx
b. New Projects			
(1) Product P	xxxx	xxxx	xxxx
(2) Product Q	xxxx	xxxx	xxxx
(3) Product R	xxxx	xxxx	xxxx
Total new products	XXXX	XXXX	XXXX
3. Basic Research			
a. Projects in progress			
(1) Item S	xxxx	xxxx	xxxx
(2) Item T	xxxx	xxxx	xxxx
b. New Projects			
(1) Item U	xxxx	xxxx	xxxx
(2) Item V	xxxx	xxxx	xxxx
Total basic research	XXXX	XXXX	XXXX
4. Balance for unauthorized projects	xxxx	xxxx	xxxx
	$XXXXX	$XXXXX	$XXXXX

[a]Source: Adolph G. Lurie, "Controlling Research Costs with a Budget," *Administrative Control and Executive Action*, pp. 282-283.

Figure 10.--Detailed project budget for R and D[a]

PROJECT BUDGET
Project A12345
Period 1 to 4, 1962

	Expense Pd. 1	Expense Pd. 2	Expense Pd. 3	Expense Pd. 4
Labor				
1. J. Jones	xxx	xxx	xxx	xxx
2. Jr. Engr.	xxx	-	xxx	xxx
3. Technician	-	xxx	-	xxx
Total Direct Labor	xxx	xxx	xxx	xxx
Fringe Benefits				
(12% of direct labor)	xxx	xxx	xxx	xxx
Materials and supplies				
(8% of direct labor)	xxx	xxx	xxx	xxx
Special materials				
1. X-ray Equip.	-	-	xxx	xxx
2. Shielded room	-	-	xxx	xxx
Miscellaneous				
1. Consultant fees	xxx	xxx	xxx	-
2. Travel expenses	xxx	-	-	xxx
Total Cost for period	XXXX	XXXX	XXXX	XXXX

[a]Source: James Brian Quinn, "Budgeting for Research," Handbook of Industrial Research Management, Figure 3, p. 303.

Some companies only budget labor costs by projects because they feel that material and supplies costs are not worth detailed planning. These companies normally include materials and supplies on a separate expense budget. Few companies budget overhead directly to projects unless the work is being sold to an outside organization. Government contracts usually include the overhead costs, and therefore this item should be included in the separate project budget.

The Capital Budget.--Along with the classification and project budgets, research groups frequently prepare a capital acquisition plan. This plan or budget usually includes such items as special or general test equipment. Although this equipment may be directly associated with a project included in the project budget, it is usually submitted separately. In addition, most organizations realize that it is not possible to forecast all equipment needs, and consequently, the capital plan often includes a large miscellaneous section.

Once the research budgets are prepared, they provide the basis for subsequent control to make sure that plans and projects are carried out in accordance with prescribed objectives. As the projects and programs continue, management should periodically review and make budget revisions. Unused funds are shifted from one project to another, new products are introduced, and unpromising projects are discontinued.

Cost Control

Generally, the objective of a financial control system is to ensure that a company does not run out of money. The major objectives of a financial control system of any activity within a company would include the following:

1. To provide cost information useful in planning and controlling cost of research.

2. To determine the amount of research cost applicable to various projects, products, and processes.

3. To provide data for periodic company financial reports.[1]

Although the objectives of cost control within a research activity are the same as other activities within a concern, the technique involved is ordinarily somewhat different because research activities are largely non-repetitive and the end product may be only basic knowledge rather than a tangible product or process.

Control over research costs is concerned primarily with keeping actual costs in line with the budgeted estimates. Generally the purposes of cost control in its application to research activities are:

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[1] Walter B. McFarland, "Research Cost Accounting and Control," Handbook of Industrial Research Management, ed. Carl Heyel, p. 314.

1. To make sure that the plan expressed in the budget is followed by directing funds into projects of types desired.

2. To avoid spending research funds on nonproductive or nonresearch activities.

3. To stimulate an attitude of dollar-consciousness so that research personnel will attempt to perform as much research as possible for the funds available.

4. To keep the total spent for research within the limit set by the appropriation for the period.[1]

Defining costs

A clear definition of what is to be included in research and development costs is required as a basis if costs are to be used as reliable guides in managerial decision making. Maurice J. Moss has described one company's practice as follows:

What Should Be Included--

1. Pure research, i.e., direct research or experimentation on general problems having no particular connection with the various products currently being manufactured by the plant.

2. Projects directing experimental or developmental effort toward the creation of new processes or new product or group of products to be manufactured by the plant. It is not intended that this should cover minor changes in which an existing product is replaced by, or improved by another. Major developments resulting in an entirely new product or process should be included, although they replace current products.

3. Projects directing experimental or development effort toward any improvement to a specific product already being manufactured by the plant or an

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[1] *Ibid.*, p. 325.

improvement in an existing process. This category would include any work necessary to correct production difficulties which have existed in products or processes since the product was considered acceptable for the trade.

4. All further work beyond the developmental stage necessary to get a new product, model, or item of equipment ready for normal production and sale.

5. Projects for the purpose of designing and constructing new types of equipment or improvements to existing equipment which shall be used in our manufacturing processes and which will effect a change in any existing process in the plant.

What Should Not Be included--

1. Technical advice or service rendered to production departments in order to help them out of difficulty or to carry on their normal operations.

2. Trouble shooting which is necessary to correct production difficulties which occur from time to time and which have reduced normal standards of products or processes.

3. Any other work done which is essential to normal operations (in contrast to new work which can be done, or not done, depending on the wishes of management).

4. The cost of producing, experimentally or otherwise, any material or article on the specific order of a customer when the material or article cannot reasonably be expected to lead to a product which will be added to our regular line.

5. Routine tests necessary for normal production procedure on a regular product.[1]

Classifying costs

In classifying research costs it is essential to begin

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[1] Maurice J. Moss, "Development Costs Incurred in the Plant," N.A.C.A. Bulletin (May, 1954), pp. 1115-1116 quoted in "Accounting for Research and Development Costs," NA.C.A. Bulletin (June, 1955), pp. 1384-1385.

with the purposes for which the costs are desired by management at various levels. In classifying research costs answers to the following questions should be considered:

1. How much was spent for R and D?

2. Who spent it?

3. For what were the costs incurred?

4. What was the application of the research effort? (i.e., classification by project and division.)[1]

In accounting for the total expense for research, one or more control accounts are needed. For example, a company might use these accounts: research expense, which would include the costs of operating a research center, pilot plants, outside services, and staff expenses; research development expense, which would include tests made by the company at the request of the R and D center; and engineering development expense, which would include costs incurred in the development and application of a new product or process.

In determining the amount spent on research and development, a clear understanding of what is to be included in research costs must be established. Since the research department must justify expenditures in terms of results, it should only be charged with the costs of research activities. For example, fundamental or basic research should be included, since it covers work leading to new technology

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[1] McFarland, loc. cit., p. 317.

although the work may have no bearing on present products. At the same time, other items seem to get into the research budget although they should not be there. For example, the cost of technical advice to help the product department out of difficulty; trouble shooting to correct product errors; cost-reduction activities in the production department; and technical services to the marketing department do not belong in a research account. All work of a service nature should be charged to the department for which it is performed.

Another important decision is to establish when research responsibility and cost ends. The following guides have been used in terminating costs:

1. When production accepts the product or process.
2. When commercial sale begins.
3. When a pilot plant produces small quantities for sale.
4. When the product is turned over to the engineering department for commercial design.
5. When production drawings, a working model, and standard manufacturing practices are complete.
6. When the product has been manufactured long enough to show that it can be produced in quantity.
7. When the product is transferred to a manufacturing company or product division.[1]

The answer to the question, "Who spent it?" is fairly easy if responsibility codes are established. By

[1] Edward P. Burnham, "Controlling the Costs of Research," Administrative Control and Executive Action, pp. 273-274.

establishing codes to identify various laboratories and subdivisions, the spender can be readily identified.

For proper planning and control, management must know for what purpose costs are incurred. Research costs arise from such basic sources as salaries, supplies, and rent. However, other expenses peculiar to research activities are also incurred. The various sources or items of expenditure should be established which will be most helpful to management control.

Financial control is primarily exercised by controlling the application of effort and facilities to the various programs and projects. Here it is important to know how much was spent by type of research and for individual products or processes. A cumulative record of costs incurred as work progresses on individual projects is essential to financial control.

The objective of cost control is not to reduce the amount spent on research. If the actual amount of funds spent for research is less than the budgeted amount it is likely that the planned work is not progressing as it should. Cost control is attained by the control of time, supplies, and services devoted to the research effort.

In research a considerable portion of the expense is composed of salaries and charges related to plant and equipment. These costs are more or less fixed as long as the

program is not altered. Records showing how employees time is being used is one of the most useful management control tools. One of the important aspects of cost control as applied to research and development is summed up by Walter B. McFarland, Manager of Research, National Association of Accountants when he says:

> . . . in applying control techniques to research costs, time of scientists and technicians should not be consumed with avoidable paper work, nor should accounting requirements restrict research operations. Instead, the proper function of accounting is to help research management get more research for the funds available and to relieve research personnel of financial record-keeping functions.[1]

Matching R and D cost with sales income.--Two alternatives are available for matching research and development costs with sales income:

1. Charge cost against sales income of the period in which the costs are incurred.

2. Defer research costs and amortize these costs over subsequent periods.

Usually costs are charges against current expenses for the following reasons:

1. Research is a recurring annual cost of continuing in business. In many respects, it is similar to advertising and general administrative expenses. To expense such costs and to take them as a tax deduction in the year incurred is generally considered to be sound financial management.

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[1]McFarland, loc. cit., p. 330.

2. Benefits from specific research expenditures are always uncertain and years may pass before success or failure of a project becomes apparent. To defer costs of a project until the outcome is known may result in building up a large asset account balance of uncertain value. If this accumulation of costs then has to be written off, annual profits may be distorted. To avoid such problems, management usually prefers not to capitalize research costs.

3. Benefits received from research can seldom be related to sales income received in any given period. Many projects which fail to accomplish their objectives yield incidental knowledge which proves to have great value at some future time. Moreover, the useful life of knowledge gained by research cannot be predicted with sufficient reliability to guide amortization of costs over the future periods benefitted.

4. Failure to match costs and income from individual projects does not distort annual net income when research costs are consistently expensed, if the amount spent for research is reasonably stable from year to year.[1]

Certain conditions may lead companies to defer research and development costs. The principal conditions under which deferral may be considered are:

1. When research of major scope is done for outsiders on a contract basis, costs applicable to each contract are accumulated and charged against income from the contract when the customer is billed. The situation is analogous to manufacture of goods to a customer's order, and the same methods of accounting for costs by job orders are appropriate.

2. Costs incurred for research projects which require unusually large expenditures for a specific income-producing objective . . . are sometimes temporarily capitalized.

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[1] *Ibid.*, p. 331.

After income from the project begins to flow in, the accumulated research costs are amortized over a period of two or three years. . . . Capitalization under such circumstances carries the risk of serious impact on a company's financial position if a project fails. . . .[1]

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[1]*Ibid.*, pp. 331-332.

CHAPTER VI

PATENT MANAGEMENT

The philosophy which forms the basis for the American patent system was framed by our forefathers in the American Constitution:

> The Congress shall have Power . . . To promote the Progress of Science and useful Arts, by securing for limited Times to . . . Inventors the exclusive Right to their . . . Discoveries; . . .[1]

> The intensive interest of the founders . . . is further evidenced by the fact that George Washington, in his First Message to Congress, stated, "I cannot forebear intimating to you the expedience of giving effectual encouragement . . . to the exertions of skill and genius in producing new and useful inventions."[2]

The patent laws of the United States were contemplated by the authors of the United States Constitution and are today codified as Title 35 of the United States Code. No discussion of the managerial aspects of industrial research and development would be complete without considering the business and legal considerations of patent policies. Management must be knowledgeable in both of these areas.

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[1] U. S., Constitution, Art. 1, Sec. 8, 8th clause.

[2] Roger H. Lueck, "Patents For Federally Financed Research: Title vs. License Policy," Research Management, V (March, 1962), 134.

Basically, the purpose of patent law is to create a property right for the inventor and to exclude others for a limited period from the use of an invention. In discussing the impact of patent law upon research, H. J. Schneider, a lecturer on patent law has this to say:

> The patent system today, as an incentive to continued investment in research, appears to be most useful in promoting the progress of science. This incentive operates to bring the inventive fruits of research to market through the exclusivity offered by patent rights in recouping the cost and risk involved. Whether or not the patent incentive directly stimulates invention depends upon the inventor. . . . some inventors chose to assume all the risks of making and marketing. . . . Patent protection is . . . an incentive to public disclosure of new inventions. . . . Whether or not secret use is a real alternative to patents . . . depends upon the situation; a head start of a few months may be adequate to recoup research costs in some cases and totally inadequate in others.[1]

There is a certain relationship between patents and research; the two are not inseparable. In some cases patent rights are vital to a company, and some research, no matter how useful, is not patentable. However, one thing can be definitely said, in looking ahead, patents and competition are inseparable. Companies which do not move promptly to patent an invention, will have no assurance that others will not patent the product.

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[1]Homer J. Schneider, "Patents," Handbook of Industrial Research Management, ed. Carl Heyel, p. 158. This quote and subsequent comments in this chapter regarding patents are largely the work of Homer J. Schneider, "Patents," Handbook of Industrial Research Management, pp. 156-180.

Patent Potential

The ultimate objective of the time, money, and effort spent in patenting a product or process is to create a larger return on investment or a greater profit for the company. What are some of the ways a patent can be employed to realize a greater profit for the concern?

The primary use of a patent is to protect an exclusive market. If the patent provides a competitive advantage and excludes others from making, using, or selling the product, the company is in a position to maximize profits on the product. One patent alone may establish the position of the manufacturer and enable him to market a full line of supplemental products.

A second use of the patent is to share a market by licensing competitors. Cash returns from royalties are sometimes preferable when factors such as the following are present:

1. The licensing of other manufacturers to assist in expanding a market.

2. A company may, for various reasons, be unable to supply a short-lived demand.

3. A relatively quick return by licensing may help finance further research.

Although the primary uses of patents are indicated in the preceding paragraphs, other applications are worthy of note. One domain of research is to develop products well

ahead of the market. The purpose of the patent is to protect these products for future marketing. Other patent holdings are directed toward gaining a foothold in a new field. And still another value of the patent is to establish a defensive right or priority of an invention against later inventors.

Evaluating Patent Property

A company involved in research ordinarily has the intent to create patent rights from research inventions. Therefore, there is a responsibility placed on research management to establish a patent program for acquiring title to patent rights. Basically, there must be an agreement between the research employee and employer to the effect that the employer has the right to inventions made by employees. In addition, various written records of inventions are important for both administrative and legal reasons. It is beyond the scope of this thesis to discuss the details of these written agreements and records.

Periodic reviews of the records and invention reports are essential for long range success in a patent program. Decisions to file patent applications are based on the estimate of future value of the invention, although this is often difficult because the projected value is frequently undeterminable. However, the advantages, the limitations, and the implications of the technological value of the inventions must be considered in making the decision as to the

feasible patentability of the product.

The final decision to file or not to file is primarily an economic one. Simply because a considerable amount of money has been spent in research and development is not sufficient reason to spend more money on patenting the results of research. Considerations to be taken into account should include:

1. The probable value of the patent to the company. Management must consider the protection of an exclusive market, the protection of company prestige, the morale of the research inventor, and advances being made by competitors in the field.

2. Doubts concerning the commercial value of the patent, are usually resolved in favor of patenting. Very infrequently are cases an open-and-shut matter. Inventions which are considered speculative are usually promising in that the future is always uncertain.

3. Timing is of the essence in filing a patent. Competitors may have received some publicity concerning the research efforts, and a delay in filing may lead to an inability to prove priority with respect to others who file at an earlier date.

The Patent Counsel

The studies of the Patent, Trademark, and Copyright Foundation of The George Washington University show that

between 1946 and 1959, there were 527,000 patents issued.[1] With this staggering number of patents the job of the company patent attorney to protect the company's overall interests is an important one. Not only does the preparation and prosecution of patent applications require highly specialized skills, but the protection of patent property requires a high degree of competence. Included among the more important functions of the patent counsel or attorney are the following:

1. He must prepare in detail the applications for the filing of patents in the Patent Office. Here a knowledge and complete understanding of the invention is necessary in order to eliminate non-essential details and generalizations.

2. He usually participates in or conducts the negotiations involving contracts which affect patent rights. For example, a contract provision with the government often provides for releasing patent rights in future inventions. In agreements of this type, provisions must be made to patent inventions already made or to exploit patents obtained in other areas.

3. He must control and supervise patent litigation initiated by or against the company. In addition, an important responsibility of the counsel is to avoid suits by holders of adverse patent rights. A close liaison between the research department and the patent counsel is

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[1]Lueck, loc. cit., p. 141.

helpful in order that remedial action can be taken before large expenditures are made on unmarketable products.

In summary, all of the results of research do not result in inventions. Inventions are sometimes difficult to come by. In the final analysis, "The variables in the relationship between dollars spent for research and inventive results can be ameliorated by patenting and skillfully employing the inventions made."[1]

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[1] Schneider, loc. cit., p. 178.

SUMMARY

When an activity grows from a very modest beginning to major status, it is sometimes difficult to see the "forest for the trees." This is the case of industrial research and development. The position of research in the category of big business is obvious after indicating some of the trends in the field of research and development today and in the past. In 1940, less than one-half billion dollars was spent for R and D, and in 1961 over $14 billion was spent. All indications are that there will be an increased annual rate of spending for R and D in the years to come. The rate of economic growth which has characterized the United States in the past indicates the importance of research and development in American industry today and in the future. The expanding Gross National Product of the United States during the past 25 years has been accompanied by a corresponding or even more rapid increase in R and D expenditures. The future seems clear: future economic growth means expanding research and development activities.

Research and development in today's era of unprecedented technological activity and progress appears to have a more important effect in the future of a company than any other major effort in which a company is engaged. This is leading

top company executives to think more and more about the improvement of the management of research activities. The natural stimulus behind this concern stems from the rapid growth rate of research, the projected growth for the next decade, the role of science and technology in the economic growth of the nation, the interest in increased profits, and lastly the need of better management because of increased competition. There is a realization on the part of management that research is required for competitive survival alone in many industries. Without a doubt, R and D has become one of the major components of modern industry, and has become a powerful instrument in economic development and national prestige.

The following facts cannot be disputed. In current dollars, outlays for industrial research and development increase from \$3.6 billion in 1954, to \$10.5 billion in 1961, an increase of almost 200 per cent; in 1960, 387,000 scientists and engineers were employed in all sectors of the economy as compared with 223,000 in 1954; and the total number of persons employed in company R and D laboratories increased from 200,000 in 1950, to 780,000 in 1960, during which time the total labor force in the United States increased by only one-eighth. The trends of the past decade obviously cannot be continued indefinitely; however, it is predicted that the total spending for R and D in the United States

will probably reach the $15.5 billion mark for 1962, and it is probable that by 1970 $30-$40 billion will be the annual expenditure for research and development. In 1962 the expenditures for space programs alone are likely to reach the $5 billion figure, an increase of $1.5 billion over 1961.

This rapid growth and the relative newness of research in American industry has created many management problems. As a result of the need of industrial research for competitive survival and the resultant increased expenditures directed toward research and development, management has developed a realization that there must be an improvement in the effectiveness and efficiency in the R and D area. Directly related to effectiveness and efficiency of management are the problems of establishing corporate objectives, integrating the objectives and programs of research with corporate objectives, and planning, budgeting, and controlling the research function.

In order to function more effectively and efficiently the following management techniques must be considered:

1. Total corporate objectives must be established. These objectives must be of such scope and vision so as to provide meaningful guidance to research programs. In establishing a firm set of corporate objectives which stimulate research in the proper direction, certain long-range

corporate planning problems must be considered. The company must decide what kind of business it wants to be in and the kind of markets in which it will compete; the company must decide whether it will compete in a wide variety of products or concentrate on only a few major product items; the company must determine its rate of growth which should be based on company advantages and particular limitations; and the company must determine to what extent growth will depend on research, as growth by research is only one of the methods of company expansion.

2. After establishing the basic corporate objectives, a company should look ahead to the forecasts of future product needs and trends. It is important to consider economic, sociological, and technological forecasts before detailed research programs are established.

3. Return on investment and growth of earnings are undoubtedly the most crucial profit standards of a company. It is therefore necessary to take a close look at past and future sales, profit, and capital requirements for both existing and proposed products and processes. This should culminate in a five- to ten-year corporate profit plan.

4. The last step in the planning stage should be the development of an overall business strategy based upon corporate objectives, forecasts, and the projected profit plan. This research strategy should be based on the future market and customer trends, and how the company can best meet its objectives in light of competition and other opposing pressures. In general this strategic plan should emphasize company strengths and minimize to a great extent the strengths of competitors. The effect of this overall plan should permit capitalization on long-term opportunities which might be difficult to appreciate on a short-term basis.

5. There must be established a system of selecting research projects that fit company operations, objectives, and plans for the future. It has been found that there is no "best" source for ideas and proposals for new products and processes, therefore all sources should be considered. In addition a screening method should be established in order to decide upon the projects which fit the interests and needs of the company. Two critical considerations in connection with the selection of a project include: (1) the amount of working capital available which can be devoted

to the project and (2) the amount of investment capital available to utilize the ultimate results of the research effort. Companies have been known to invent a product that was beyond the company's financial capability to commercialize.

6. Research must be controlled, however the problem in R and D management is to strike a critical balance of controlling yet allowing enough freedom so that creative effort of the scientist is not stifled in the process. One of the primary control tools is the research budget. The best indication that a manager has of what is going on is by studying actual expenditures in comparison with the budgeted expenditures. In establishing the research budget the amount to be spent is an important decision, and various quantitative and qualitative factors must be considered in arriving at the final figure. In line with budgeting, control of costs plays an important part. Costs must be defined and classified, a system of cost control must be established, and an important dividing line must be established at the point when research costs end and production costs begin.

7. Research must be evaluated. With the amount spent annually for research and development, managers

are thinking more and more about the results obtained from research expenditures. With an adequate evaluation system weaknesses of projects can be observed before costly mistakes are made, past performance can be utilized for planning future programs, results of research can be appraised for maximum commercial exploitation, the output of technical personnel can be better measured, and comparisons with competitors are simplified. There have been many methods proposed for the evaluation of research, there have been volumes written on the subject, but there is no uniform or generally accepted procedure for evaluating the results of the research effort. Approximately one-third of the industrial research laboratories have adopted formal evaluation procedures to some degree, however there are almost as many evaluation methods as there are research activities. Three dominant evaluation techniques are found in current thinking: (1) the quantitative approach which usually makes use of complicated formulae, (2) the qualitative approach which relies basically on managerial judgment, and (3) a compromise or integrated approach which combines the other two techniques and further subdivides the evaluation process into

a technical and economic evaluation.

8. Management must consider the patentability of the product or process which has been developed. Patent and competition are inseparable. Companies who do not move rapidly and patent a product are liable to find themselves out of a market. Competition is likely to beat them to the Patent Office.

Some of the basic problem areas of industrial research management have been discussed in this paper, together with some of the managerial methods and techniques used in industry today to cope with these problems. The public-private sector of research and development and the associated problems have been intentionally eliminated as this sector would constitute a study in itself. The emphasis purposely has been placed on the various problems faced by R and D management and the techniques that are being used in industry today. No definite solutions have been proposed. The answers to the many problems faced by today's growing research activities is the role of research management. They must look ahead, attempt to integrate the goals and objectives of the company with the programs of the research activities. If there is a conflict between the philosophy of top management and research directors, both will be working toward endless answers. In order to realize corporate objectives, to maximize profits, to increase

basic knowledge as rapidly as possible, and to stimulate research activities, there must be a realization that research is not a separate activity. Research is a big business, and for maximum results there must be better overall management planning, evaluating, and control.

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